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PRODUCT ENGINEERING

MAY
1935

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Beginning a series of four articles that explain the vital facts relative to chain drives and clarify the recommended practices for their design and application . . . . . PAGE 169

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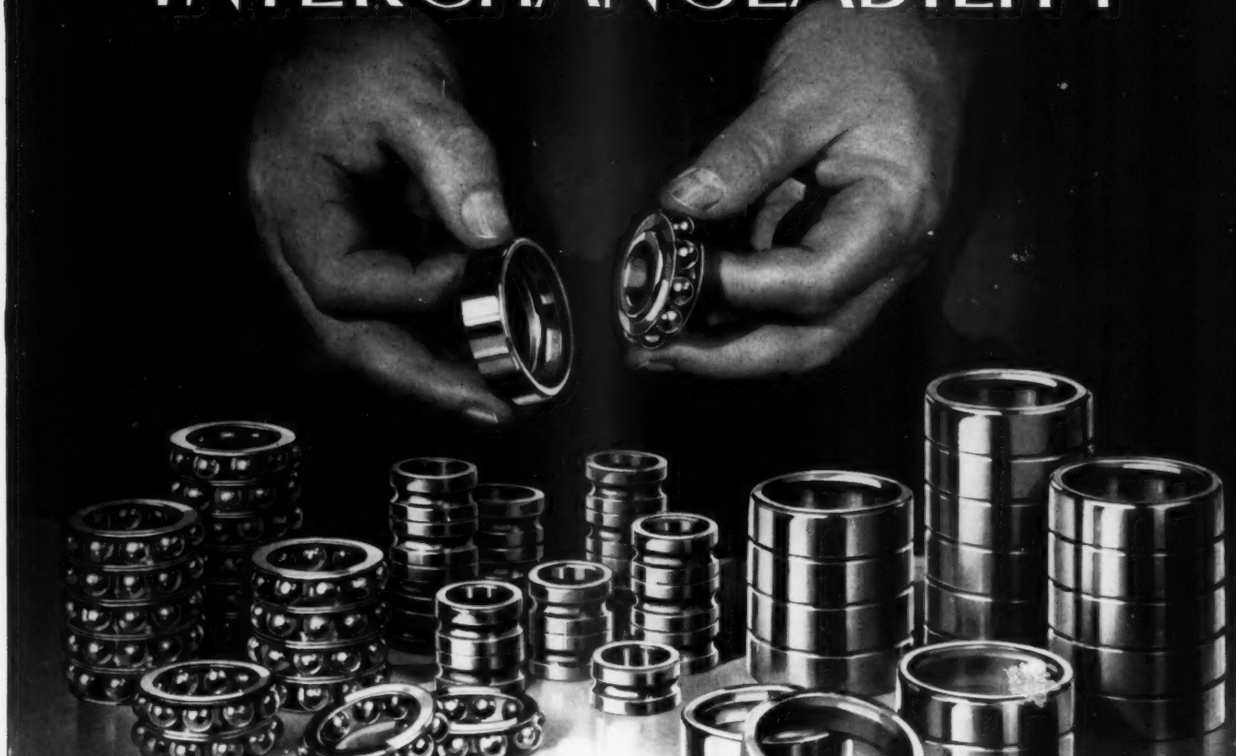
Mechanical Design • Product Development

McGRAW-HILL PUBLISHING COMPANY, INC.

A QUARTER CENTURY of INTERCHANGEABILITY



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PRODUCT ENGINEERING

VOLUME 6 NUMBER 5

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Next Month

Many articles have appeared in both newspapers and technical magazines describing new railroad equipment. Our lead article next month analyzes the mechanical design of this new equipment with reference to the new design principles employed, changes brought about through the use of new materials, how design aims tied in with service requirements and the added revenue value of new equipments resulting from the attention given to finish and appearance.

June *P.E.* will also include a feature article on the application of motors, controls and electrical devices; a continuation of the article on chain drives; and articles on finishing die-castings, leather packings, machine lighting, plus the usual departments.

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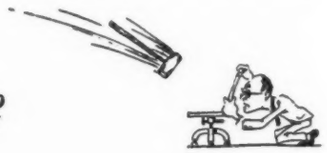
Intimate Correspondence



More Gear Data

PRODUCT ENGINEERING
NEW YORK

You have been publishing some very interesting and helpful data sheets on gear design calculations, which have been appreciated.

Due to the fact that data covering the design and calculations of herringbone gear teeth is hard to obtain, may we suggest that you publish some data sheets covering this subject in future issues. We will look forward with interest to receiving this information through the medium of *Product Engineering.*

T.N.W.
Bridgeport, Conn.

READERS' service is our primary aim. T.N.W. will not be disappointed in looking forward to receiving the data on herringbone gear teeth through the medium of *Product Engineering.* Incidentally we are also including helical gearing in his request. Of course, we have already started the ball rolling by requesting some of the recognized authorities on this subject to furnish us with the desired contribution.

We Have Done It

PRODUCT ENGINEERING
NEW YORK

Generally I have to go through all of the back copies of *Product Engineering* for two or three years, page by page, until I find what I am seeking. It may be an article or series of articles in which I was not interested at the time it was published, or perhaps a new product placed on the market, or it may be a lowly advertisement of some product which I might need in one of my brain childs.

Here is my suggestion of a solution to this problem: Make up an index of all the back copies of *Product Engineering,* properly cross referenced so that any particular article, new product, product development, communication and comment, news, new materials or parts, or any of the other valuable information your magazine contains, can be found readily.

This index could be made up under separate cover, or could be published in several issues giving one year's complete index at a time until the whole series was published. A good plan would be to publish the index for the year in the December issue.

There is always room for a magazine as valuable as *Product Engineering* in the files of any far-sighted engineer, and the yearly index would be invaluable to him.

J.E.A., Research Engineer
Schenectady, N. Y.

APPARENTLY the Christmas spirit and activity has been interfering with J.E.A.'s careful perusal of our December numbers. Ever since 1930 when *Product Engineering* was started there has been a comprehensive index published in the December number. This index covers all of the items mentioned by J.E.A. except the news section and the new materials and parts section.

We are wondering how many of our readers would be interested in an annual index of the "New Materials and Parts" announcements that appear in *Product Engineering.*

Some People Can't Wait

On April 9 we received the following telegram from Los Angeles, California:

REGARDING ARTICLE PRODUCT ENGINEERING FOR APRIL IS IT POSSIBLE TO OBTAIN SECOND ARTICLE BY MR. DORR IN ADVANCE STOP INFORMATION CONTAINED THEREIN WILL BE OF GREAT BENEFIT TO US IMMEDIATELY AS WE ARE ABOUT TO ORDER LARGE QUANTITY OF LEATHER PACKING.

S. J. CORP.
Los Angeles, Calif."

FAR be it from us to stop the wheels of progress. Photostatic copies of the desired information were immediately dispatched via air mail. But we must warn our readers that we cannot make a general practice of issuing the magazine before it comes off the press. Of course, in a situation like the above, we are always glad to be of service.

Again Page Mr. Dorr

PRODUCT ENGINEERING
NEW YORK

We would like very much to have the address of the Dorr-Patterson Engineering Company in reference to the article by their Mr. George M. Dorr in your April edition of *Product Engineering,* page 139.

As this matter is rather urgent, if you can get in touch with Mr. Dorr and ask him to send us or tell us where we can get catalogs on metallic packing and cup rings for small diameter cylinders, say from ½ in. up to 1½ in., we will appreciate it very much.

THE B.M.Co.
Cambridge, Mass.

WE IMMEDIATELY replied with the desired information, Mr. Dorr's address being 3362 Wight Street, Detroit, Mich. Often it is the little things that count and we can appreciate the B.M.Co.'s aggravation in trying to find the manufacturers of metallic packings and cup rings. There is the old fable of the world beating a path to the door of the manufacturer of perfect mouse traps, but what we want to know is how are you going to find the door before the path has been beaten. This is not a pun; we are perfectly serious.

Please Be More Specific

PRODUCT ENGINEERING
NEW YORK

It now develops that I am to have my office at the company's main office and I kindly asked that you change my address on your records to correspond with the change.

In the shuffle I have not received my January, 1935 issue. Is it possible that you could send me one? You are doing a very excellent work—how about discussing some oil field machinery design problems once in a while.

V.E.B., Supervisor
Tulsa, Okla.

NATURALLY we do not have any objection to discussing any design problems that our readers might wish to have presented. We recognize that there are many special problems in the design of oil field equipment, at the same time these same problems are reflected in many other industries. But we are wondering exactly what the problems are that V.E.B. wishes to have discussed. And perhaps there are other of our readers who likewise want some information along the same lines. If so, a penny post card addressed to the editor will help a lot.

Another Oil Man Is Heard From

PRODUCT ENGINEERING
NEW YORK

On page 87 of your March 1935 issue we note that there have been recent improvements in the process for chemical rust-proofing steel used in automobiles. Although we do not manufacture automobiles we are continuously attempting to improve the finish of our product, which is oil field equipment. Therefore, we would like to have you put us in touch with a firm that can give us additional information regarding the improved process that is mentioned.

W.S., Chief Engineer
The P.R.&R. Co.
Parkersburg, W. Va.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

MCGRAW-HILL PUBLISHING CO., INC. MAY 1935 VOLUME SIX, NUMBER FIVE

Shall Patent Laws Be Scrapped?

ENCOURAGED by the monopolistic privileges granted by patents, American initiative and inventive ingenuity created the products which are the foundation of our vast industrial enterprises. The steamboat, telegraph, telephone, phonograph, electric lamp, radio, automobile, airplane and harvesting machinery are a few of the outstanding developments. Scientific research and invention, encouraged by patent protection, have built our vast material civilization.

A few inventors have made large profits from their discoveries and developments. In many instances much of the profit went to those who risked their money in financing the new development, to men who had the business ability to properly market the product or who developed the invention from an idea on paper or a crude model to a marketable product. But the odds are heavily against those who are seeking profit from inventions. Less than one out of 1,000 patents get beyond the development stages; even fewer show a profit. Indeed, the life of the patent has often expired before it has earned the costs of development.

Our patent system was instituted for the purpose of guaranteeing to inventors the exploitation of their patents free of competition. This was to enable them to get "all that the trade will bear." During the life of the patent, their profits would presumably be proportional to the value of their accomplishment to society, because there would not be the restriction of free competition.

In sharp contrast with the spirit of our Patent Law, there has been organized, under the imposing name of American Economic Foundation, a group "to secure for the American people the economical benefits of science and industry by opposing the abuses of patent monopolies, patent pools and royalty dictatorship, in restraint of trade." The quote is from the written objectives of the society. Specifically what abuses are referred to are not mentioned. Nor was any reply received to an inquiry on this point addressed to the headquarters of the society.

A patent is a government-granted monopoly. Owners of patents have the privilege of selling or pooling them, leasing them on royalty or doing a number of other things as they see fit. By its very nature, a patent is meant to be "exploited" to the maximum monetary benefit of its owner. Rob a patent of this feature, it becomes virtually worthless.

Without patent protection, would our larger industries spend millions on research, would individuals spend time and money to develop their ideas? Admitting some abuses of the patent privilege, would not the "cure" result in more damage than the abuse? Indeed, "exploitation" of the consumer, if any, can be regarded as merely part-payment by the consumer for the innumerable benefits derived from the new inventions.

Admittedly the objectives of the American Economic Foundation are idealistic, and therein lies their danger. Perhaps these Utopian aims can be explained by the fact that the advisory board of the foundation consists of six college professors headed by an economist.

Facts to be Considered In Designing Chain Drives–I

Merely selecting a chain drive from a catalog on the basis of horsepower and speed, ignores the many important things affecting chain life and performance. This series of four articles explains chain action and manufacturers' recommendations as to pitch, speed, sprocket teeth, chain adjustment and idlers, lubrication and other facts vital to chain drives

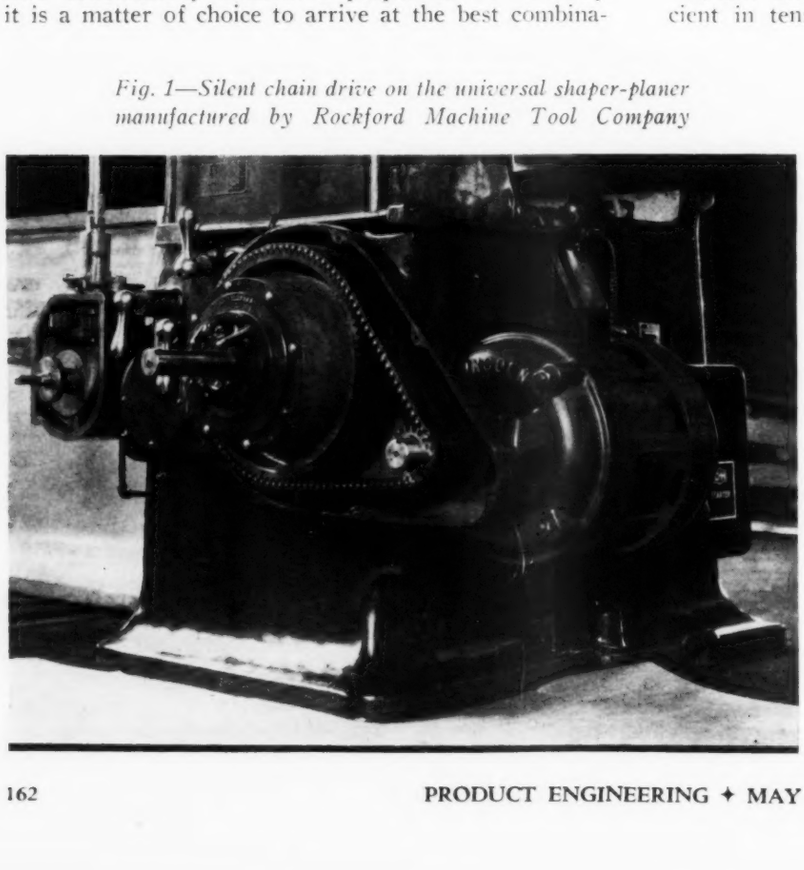
IN THE design of chain drives, the power to be transmitted and the r.p.m. of the driving and driven sprockets are definitely known quantities in the problem. Usually the center distance between the sprockets and their positions are also given. But although the motor or engine rating is usually given, the actual power requirements are frequently unknown.

Chain speed, silence of running, wear life, freedom from maintenance, and the relative first cost will vary, within limits, according to the combination of pitch, sprockets, and chain width selected. But too much emphasis should not be placed on first cost. Low cost at the expense of other requirements is false economy, especially for equipment that cannot be operated satisfactorily without a proper drive. Usually it is a matter of choice to arrive at the best combination of drive specifications. Hence, before proceeding with any actual calculations the relative importance of the various requirements should be evaluated.

Much emphasis is usually placed on selecting a chain pitch to give smooth and silent running. For business machines, bakery and laundry machinery, moving picture apparatus and similar equipment, these requirements are paramount. In countershaft drives as on diesel engines and for packaging machinery and machine tools, where there are other operating noises, it may be permissible to use a chain drive that is not entirely silent. In chain drives for cranes, steel mill machinery, construction equipment and other machinery that is inherently noisy, chain noise is not a factor.

Chain drives rarely fail because the chain is deficient in tensile strength. Chains when properly selected from horsepower tables in manufacturers' catalogs will have a factor of safety between 8.5 and 11.5 at 25 ft. per min., 24 to 32 at 1,200 ft. per min. and 42 to 54 at 2,500 ft. per min. Toothed or "silent" chains have a factor of safety between 30 and 60, in so far as tensile strength is concerned. Invariably chains wear out instead of breaking, the wear at the pins and bushings causing the chain to elongate until it rides toward the tops of the sprocket teeth.

Fig. 1—Silent chain drive on the universal shaper-planer manufactured by Rockford Machine Tool Company



In order to keep down the first cost, the chain drive should be designed to give a life commensurate with that of the machine on which it is used. On a machine used only for stand-by service or running only a few hours a day there would be no point in having a drive chain that will have a life several times that of the machine. But great care must be taken not to use a chain that is too small in

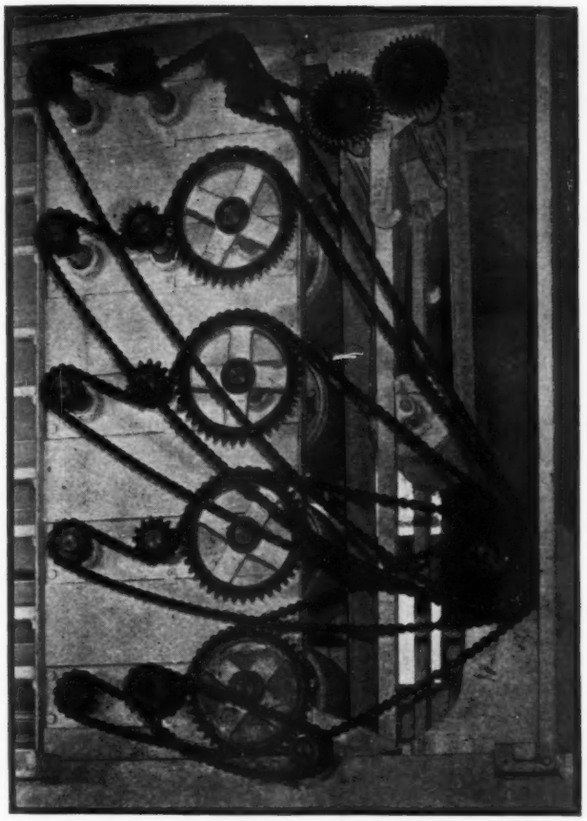


Fig. 2—An example of chain drive possibilities using idlers and multiple-driven sprockets. The drive from the motor to the main shaft is through a Reeves variable-speed unit

power transmission capacity. According to tests, 33 per cent increase in load will reduce the life of the drive to one-half, while a load increase of 50 per cent may reduce the chain life to only one-fifth of that at its rated capacity. To be on the safe side it is better to "over chain" if there is any doubt about the power requirements and service conditions of the application.

To arrive at a logical decision in the selection of the most satisfactory pitch to use for a given drive, it is necessary to consider the factors involved. The r.p.m. of both the driver and the driven sprocket are usually known from the conditions of the problem. The speed of the faster running shaft establishes the maximum pitch that should normally be used, the number of strands of roller chain or the width of the toothed or "silent" chain being chosen to accommodate the power to be transmitted.

Although figures for the "maximum r.p.m. of sprocket" are published by chain manufacturers for each pitch of chain, these are not the actual speed limits for satisfactory operation. As a general practice, over-speeding is not advisable, but under favorable conditions drives can be designed to run at speeds greatly in excess of those recommended. There are drives running satisfactorily at three times the published maximum speeds, but these are unusual and special designs. They are mentioned here merely to indicate some of the possibilities with reference to maximum chain speeds.

For either silent chains or roller chains the speed of the chain in ft. per min. will be equal to the product of the number of teeth in the sprocket, times the chain pitch in in., times the r.p.m. divided by 12. For the same number of sprocket teeth, the chain speed will be directly proportional to its pitch. This relationship is shown in Fig. 4, by the straight-line curve.

In the accompanying Fig. 3 is indicated the action of a roller chain or silent chain link as it enters and leaves the sprocket, the mechanical fundamentals being the same for both types of chain. As the trailing end of the link is entering between the sprocket teeth, the link is swinging through an angle, as indicated in the figure. It is this action which causes the impact in roller and silent chains. Although formulas for numerical values of impact are open to question because they cannot incorporate the effects of the variable factors that enter into actual applications, they do show the extent to which the impact is affected by the pitch of the chain used and the chain speed.

A paper by G. M. Bartlett for presentation at the semi-annual meeting of the Machine Shop Practice Division of the American Society of Mechanical En-

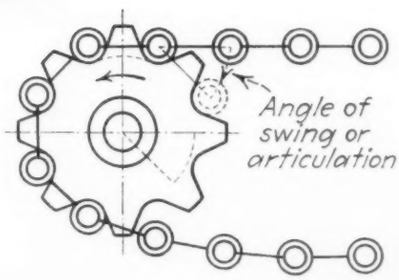
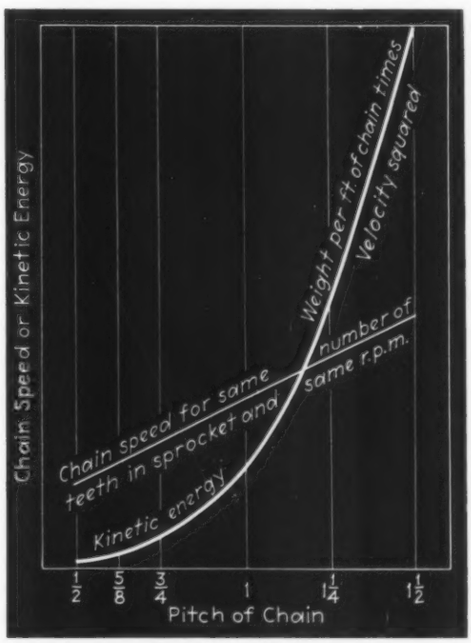


Fig. 3—As either a roller or silent chain link enters or leaves the sprocket it is swinging at an angular velocity equal to that of the sprocket

Fig. 4—For a given number of sprocket teeth and r.p.m., chain speed is proportional to pitch, but the kinetic energy increases much faster



gineers, at Cincinnati, Ohio, June 19 to 21, contains the derivation of numerous formulas for sprocket wear, impact, maximum allowable pressures and other factors. This article has been published in the April, 1935, number of the Transactions of the American Society of Mechanical Engineers.

Impact is proportional to the kinetic energies lost by the moving elements when they come together. The kinetic energy is proportional to the square of the velocity and the mass of the moving element. On this basis was constructed the curves shown in Fig. 4. The kinetic energy curve is based on the weight per foot of an arbitrarily selected make of American Standard roller chain. Although exceptions may be taken to this curve because it does not give numerical values and is inexact for reasons as stated above, yet it is sufficiently correct for all practical considerations. It strikingly shows the relative increased kinetic energy resulting from increasing the pitch of the chain.

As the kinetic energy of the swinging link is a measure of the impact between the chain links and the sprockets, the significance of the recommendations to use fine pitches, especially at high speeds, is apparent. But it must not be assumed that chain drives fail frequently because of impact. Its most marked effect is noise and it also contributes to possible roller breakage, pin wear and sprocket tooth wear. In properly designed drives the wear resulting from the turning between the pins and bushings will govern the life of the drive.

Further in connection with chain speeds is the question of possible effects because of centrifugal force. The tension created by centrifugal force can be calculated from the equation:

$$\text{Chain Centrifugal Load} = \frac{\text{Wt. per ft. of chain} \times V^2}{115{,}900}$$

This equation gives the load in pounds developed by the centrifugal force at a chain velocity of V ft. per min. and this load must be added to the horsepower load.

The above equation may be recognized as being derived from the well-known formula for the stress created in flywheel rims by centrifugal force. In this connection it is also interesting to consider the formula

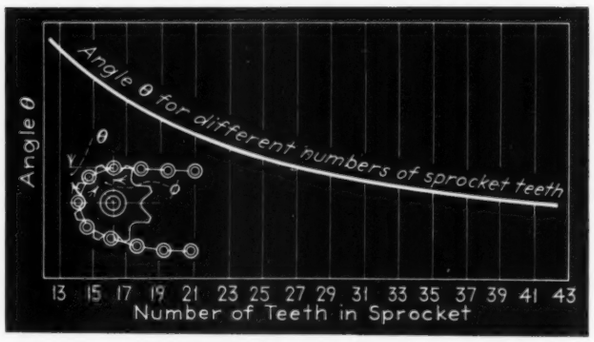

Angle θ
Angle θ for different numbers of sprocket teeth
θ
13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43
Number of Teeth in Sprocket

Fig. 5—For less than about 19 teeth, the angle θ increases rapidly, beyond 25 teeth angle θ decreases slowly, improvement in articulation being relatively small

for the calculation of permissible working loads as approved by the American Standards Association, namely:

$$T = \frac{2{,}600{,}000\,A}{V + 600} - \frac{W V^2}{115{,}900}$$

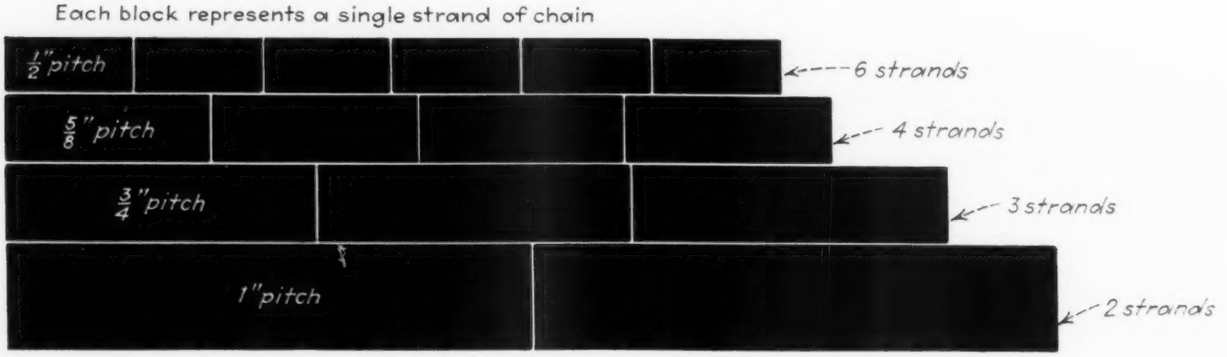
In this equation T is given as the working load in lb., A is the projected pin bearing area in sq.in., V is the chain velocity in ft. per min. and W is the weight in pounds per foot of chain. The first term in the right-hand member of this equation is empirical. It is based on an allowable unit bearing pressure of 2,600,000 divided by $(V+600)$. The last term of the equation is included in the calculations only when the chain velocity is 800 ft. per min. or more.

Sometimes the above equation is interpreted as making a double allowance for centrifugal force in that the velocity factor appears in both terms of the right-hand mmeber. But the formula is evidently intended to call for a lower allowable pin pressure at higher velocities, as interpreted in the preceding paragraph. Deducting the centrifugal force load makes T the allowable power transmitting load. Differences in the interpretation of this formula and modification of the constants in it probably account, to a large extent, for the differences in chain ratings of various manufacturers.

Centrifugal force is not a factor in establishing the rating of chain to be used, because the published ratings include allowances for centrifugal force. Therefore, centrifugal force should not be added to the calculated working load on either roller or silent chains.

In silent chains the centrifugal force factor is con-

Fig. 6—Comparison of total projected pin-bearing areas for multiple strands of roller chain, the horizontal lengths representing the net projected pin areas, power transmission capacity being in about the same proportion.



siderably greater than in roller chains because the former are heavier. But here also centrifugal force is not a dominating factor.

The required effective chain pull for transmitting the horsepower is:

$$\text{Effective Chain Pull} = \frac{\text{hp. transmitted} \times 33{,}000}{\text{chain velocity in ft. per min.}}$$

Here is seen another effect of increased chain speed, namely, a decrease in the effective chain pull required to transmit the horsepower. Usually this decrease will more than offset the numerical increase in the centrifugal load caused by the higher chain speed, and the unit bearing pressures at the pins will be decreased correspondingly, thereby tending to reduce the wear rate in so far as this factor is concerned. But for both silent and roller chains, impact and noise increases with chain speed and for a given application, the number of engagements per min. between any given link and the sprockets increases in proportion to the chain speed. For most high-speed applications a chain speed between 1,500 and 2,800 ft. per min. is the best, but much faster or slower drives can be designed to operate equally well.

The following tabulation summarizes for a given drive the effects of changes in pitch and number of teeth in the sprocket pinion:

A—With decreased pitch of chain; pitch diameter of sprockets remaining the same:

1. Chain speed remains the same.
2. Effective load pull required remains the same.
3. Unit bearing pressure on pins increases because of the smaller bearing area of the pins of the smaller chain.
4. Centrifugal load decreases because the smaller pitch chains are lighter.
5. Angular rotation between pin and bushing in going on and off the sprockets decreases.
6. Less variation in instantaneous angular velocity of the sprockets, because the "polygon" of sprocket teeth approaches nearer to a circle, as shown in Fig. 5. The limitation of this will be discussed later.
7. Less impact because with a greater number of teeth the chain links in going on and off the sprockets swing through a smaller angle.
8. Less noise or no noise from impact.
9. Longer life in proportion to the decreased wear and impact.

B—With increased number of teeth in the sprocket, the pitch remaining the same and the pitch diameter increasing with the number of teeth:

1. Chain speed increases and net chain pull increases proportionally. Centrifugal force load increases but usually remains negligible.
2. Less variation in angular velocity with less noise and impact, especially in the range of low numbers of teeth.
3. Less wear and longer life, for the same reasons that a smaller pitch on the same size sprocket gives longer life.

All other conditions remaining the same, the rate of wear at the pins will increase with the unit bearing pressure. Allowable unit bearing pressures as calculated from above equation of the American Standards Association are given in the accompanying table.

ALLOWABLE UNIT BEARING PRESSURES

Chain speed ft. per min.	Allowable unit pressure on projected area of pin lb. per sq.in.
100	3,700
1,000	1,700
2,000	1,000

Any equations or figures for allowable unit pressure on the projected pin-bearing area are empirical. Such figures are based on experimental results obtained from chains operating under "normal" conditions. But there is a wide divergence of opinion as to what may be considered "normal" conditions. Hence various chain manufacturers base their chain ratings on allowable unit pressures different from those proposed by the American Standards Association.

Comparing the allowable pin-bearing pressures as recommended by two of the leading chain manufacturers with those of the A.S.A. given above, for a velocity of 100 ft. per min. the two manufacturers allow 3,000 and 4,500 lb. per sq.in.; for 1,000 ft. per min. both manufacturers agree on an allowable pressure of 2,000 lb. per sq.in.; while for 2,000 ft. per min. one recommends 1,500 lb. per sq.in., while 1,250 lb. per sq.in. is specified by the other manufacturer.

With good lubrication, wear on the pin-bearings is exceedingly slow even with pressures much greater than any of those given above. If good lubrication could be assured, ratings for other than shock loading, impulsive driving and the like could safely be much greater than is now published. Pressures as high as 10,000 lb. per sq.in. at slow speeds would not, with good lubrication, cause rapid wear and a short chain life. Indeed, such a bearing pressure is comparable to that used in the design of some of the bearings on punch presses.

For American Standard roller chains, the bearing areas for different pitches are given in the accompanying bar chart, Fig. 6. From this it will be seen that the percentage increase in bearing area in going from $\frac{1}{2}$ in. pitch to $\frac{5}{8}$ in. pitch is more than 50 per cent, whereas the percentage increase in changing from $1\frac{1}{2}$ in. pitch to $1\frac{3}{4}$ in. pitch is not quite 20 per cent. It is evident from this that a decrease to the next lower pitch is much more significant when dealing with the smaller sizes of chain. The bar graph also gives a ready comparison of the total projected bearing area for single and multiple strands of roller chains of various pitches. The maximum allowable chain pull for a given speed will be in about the same ratio.

• **This series of articles is based on interviews and correspondence with the chief engineers of the following manufacturers:**

The Baldwin-Duckworth Chain Corporation
The Boston Gear Works
Diamond Chain and Manufacturing Company
Morse Chain Company
Ramsey Chain Company, Inc.
The Whitney Manufacturing Company

• **Their assistance in furnishing data and information and in criticizing the preliminary draft of the articles, is gratefully acknowledged.**

Applying Photo-Electric Controls

ROBERT G. SILBAR

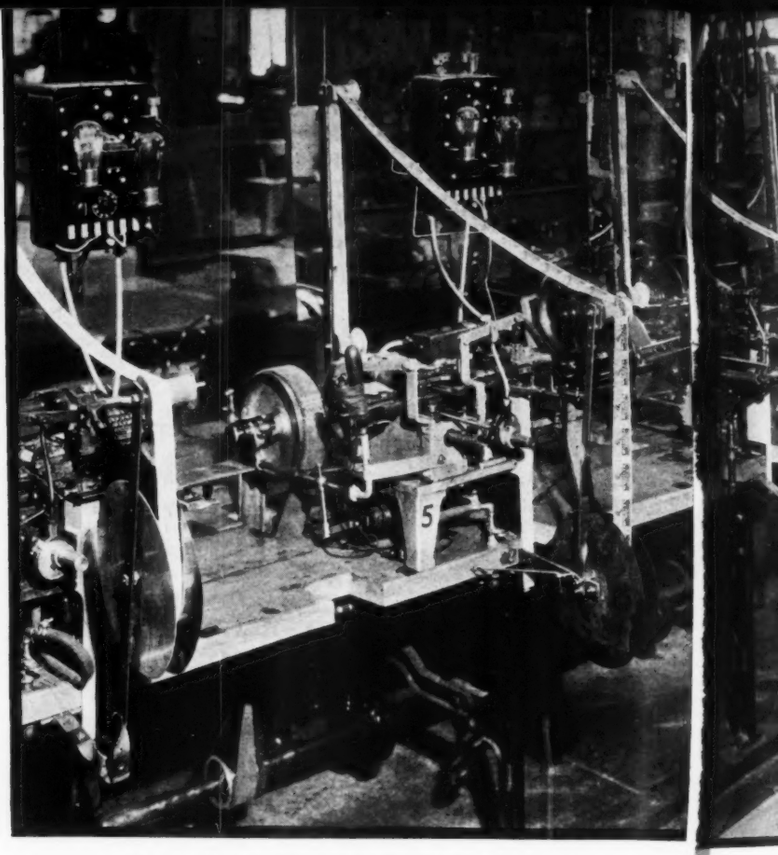


Fig. 1—In this battery of machines built by the Rose Patch and Label Company a photo-electric device centers the printing on each label

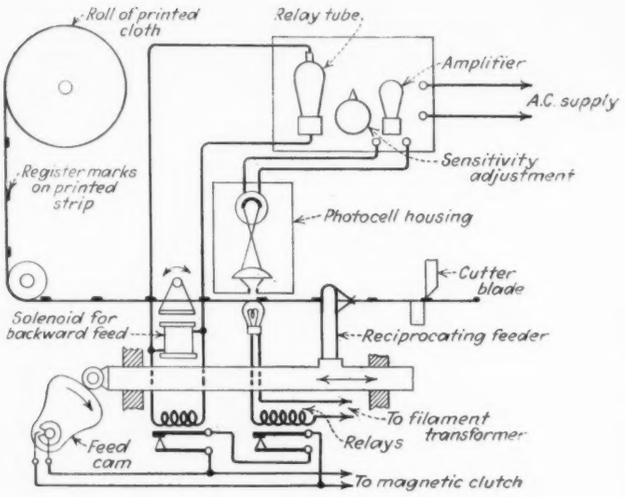


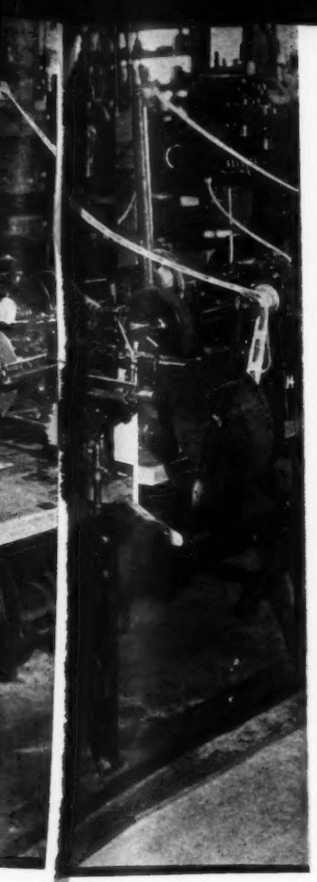
Fig. 2—Printed marks on the label strip are registered with a slit in the photocell housing before each operation of the shear, thereby spacing the printing accurately on each label

MECHANICAL controls operated by photo-electric devices can be designed to perform two types of operations: to operate with complete interruption or full intensity of the light beam, or to operate only at a predetermined level of light intensity. The first type is an "on and off" control, while the second type can be used as a "grading" device

An operation of the "on and off" type is used in the machine, shown in Fig. 1, which cuts, folds, irons and packages printed cloth labels. In this machine, individual labels are cut from a roll of printed cloth by a shear, a cam-driven feeding mechanism pulling the strip beneath the shear knife until the label is properly positioned. In the previous manually controlled machines, the cam drive was adjustable to a stroke approximately equal to the spacing between labels. To allow for stretch, uneven spacing and irregularities in the cloth, a cam-operated rocker was manually adjusted for each stroke of the shear to bring the label into register. With manual control the human factor necessarily introduced errors, and also required constant attention from one operator for each machine.

Photo-electric controls for the machine shown in Fig. 1 could be designed to register each label with a printed mark by a number of methods. The tape could be stopped at the proper position while being fed at a high rate, but such a control would require high-speed operation of a clutch and brake. Or, the machine could be designed with a mechanical feed to be adjusted to the label spacing as accurately as possible and a small, fixed correction applied by the photocell to the following feed stroke if a label was cut off long or short. This method would require corrections to be made in two directions and the corrections would be made only after an incorrect operation had been completed. In the type of photo-electric control developed for the machine shown in Fig. 1, each label is cut to the correct length, adjustment is required in only one direction and the control operation does not involve a high-speed mechanism.

Referring to the diagram, Fig. 2, the cam stroke is adjusted to feed the register mark on the tape approximately $\frac{1}{8}$ in. past the slit in the photocell housing. During this portion of the stroke the lamp is not lighted and the photo-electric relay does not operate. At the end of the cam stroke the light is turned on and a reverse feed engaged, which pulls the strip backward by arms operated by a solenoid. Reverse feed continues until the printed register mark on the label strip interrupts the light beam, which causes the photo-electric relay to open the solenoid circuit, thereby releasing the backward feed. The cutter blade, driven by another cam, shears off the label and simultaneously



the photocell lamp is turned off in preparation for the next stroke.

Although the machine cycle is about one second, none of the operations involve high-speed electrical or mechanical drives, which allows the use of an alternating current supply for the control. Only one amplifier tube is needed. The reversing solenoid is operated by a grid-controlled rectifier tube, eliminating all exposed or mechanical contacts in the circuit. Since the lamp is off during the forward feed stroke, no light shutter or switch is necessary.

To eliminate necessity for constant supervision, a magnetic clutch in the main drive stops the machine and signals the operator when proper register cannot be obtained. The clutch is disengaged by any one of three sets of control contacts. One is operated by a relay in series with the lamp circuit, and a second relay is connected in parallel with the output of the amplifier. A third switch on the feed cam opens at the end of the reverse or registering stroke. Failure of the lamp to light or the amplifier to function at the moment just before operation of the cutter blade, disengages the clutch and stops the machine.

Operation of the machine is also under control of a counter that makes a contact when a given number of labels have been cut off and fed into the folding and packaging mechanism. When the desired quantity for one package has been cut and folded, the counter disengages the magnetic clutch, thereby stopping the machine.

A second type of photo-electric control, operating on the "grading" principle, is extensively used today in several types of bean sorting machines. In all of these machines, the reflectivity of each bean is measured by a photocell, and dark or discolored beans are rejected. In one type of machine, shown in Fig. 3, beans are brought in front of the photocell one at a time on the periphery of a rotating drum shown in the diagram, Fig. 4. As the rim of the drum turns through a hopper of unsorted beans, vacuum sucks a single bean against holes in the rim, the vacuum being just sufficient to hold the bean in place. The rotating drum carries the beans into the lamp housing where a group of small electric lamps illuminates each bean as it passes in review before the photo-electric cell. Reflected light from the bean is condensed by a lens, passed through a color filter and focused on the light-sensitive surface of a photocell. The amplified photo-electric current actuates a grid-controlled rectifier or relay tube, the tube acting as a relay for an electromagnet. When discolored beans pass before the optical system, a hammer on the end of the electromagnet armature knocks the bean from the rotating drum into a chute. Good beans are scraped off the drum to fall into a hopper.

Because of the high production speed required for the bean sorter, direct-current operation is necessary for the photocell, amplifier, relay tube, and electromagnet. Since the relay tube will not reset until the supply circuit is opened, a commutator on the drum shaft interrupts the circuit of the relay tube during the time when the next bean is advancing into the scanning zone.

In common with all types of "grading" controls, one of the most difficult problems in this application was to obtain a constant sensitivity. Variations in line voltage not only change the ratio of amplification in the photocell circuit but also change the light output of the lamps. Both lamps and electronic tubes drift or age with time, and variations in temperature also introduce changes. However, methods of controlling and compensating the electrical circuits were developed so that once the sensitivity was set, the bean sorter remained constant within required limits.

Fig. 4—Decreased light reflected from imperfect beans causes the amplified photocell current to release a magnetically held spring-loaded arm

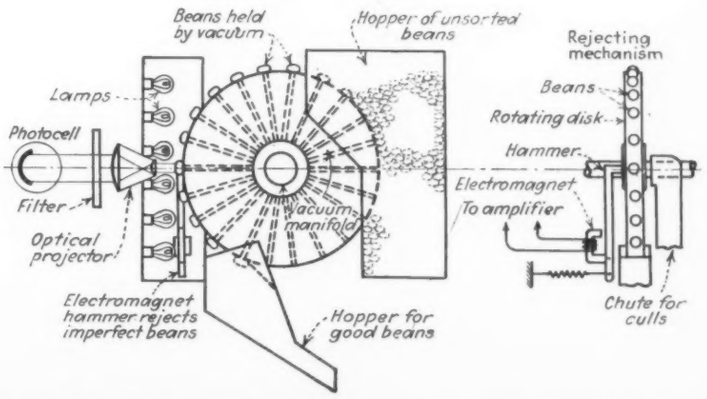
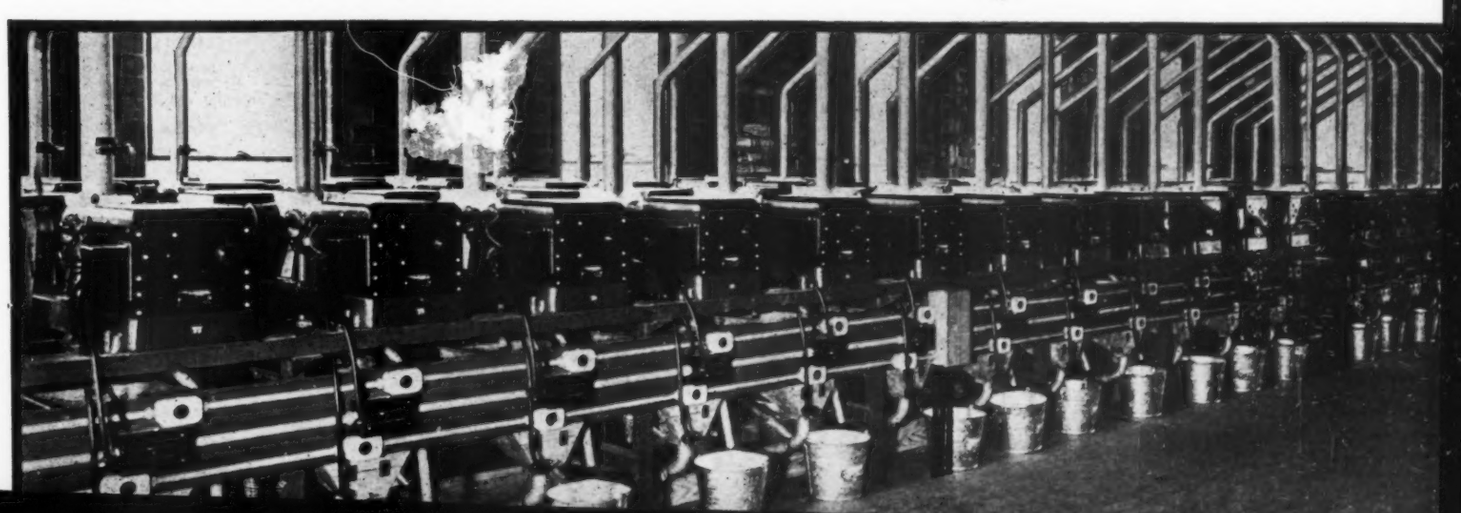


Fig. 3—Operating in pairs from a single hopper this battery of 100 photo-electric sorters in the plant of the General Bean Company will sort culls from more than 50,000 lb. of beans in a day



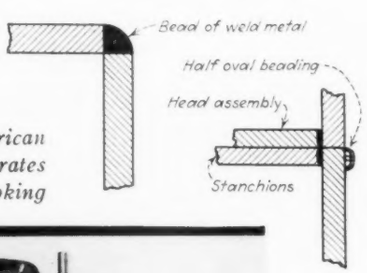
PRODUCT DEVELOPMENTS

• *Arc Welding for Appearance*

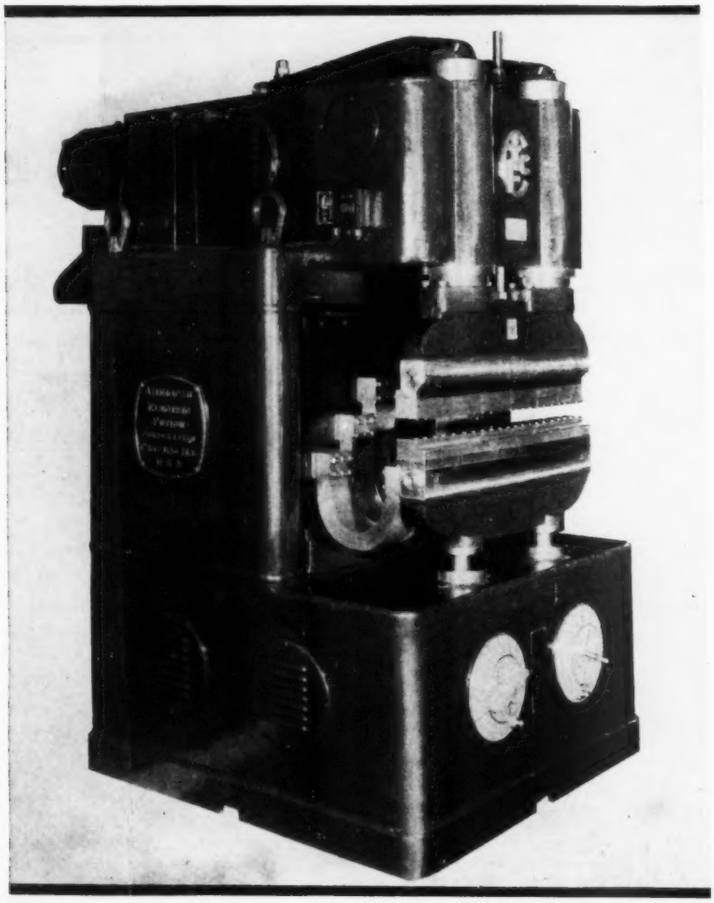
Early designs of machines constructed by welding in many instances were only a combination of angle irons, structural shapes and plates, giving an impression of ruggedness. The appearance was anything but beautiful. But the projection welder shown here, designed by the American Electric Fusion Corporation, demonstrates that a pleasing appearance is possible and practicable in an arc-welded machine.

Joints between plates meeting at right angles are given a smooth rounded contour by offsetting the plates and filling the corner with a large bead of weld metal, as shown in the diagram. Joints and breaks in the smooth surfaces are relieved by attaching a half-oval bead below the break, the bead being welded to the outer surface of the plate by small plug welds.

Arc welding also makes possible a design in which separate units are provided for each of the four parts of the machine: electrodes, pressure mechanism, current transformers and conductors, and controls for both pressure and current. All of the pressure-applying mechanism is contained in the top section, in which the housing and bearing frames are assembled entirely by welding. The two vertical plungers, actuated by toggles, move in brass bushings supported in heavy-wall iron pipes welded into the housing.



New projection welder designed by American Electric Fusion Corporation, demonstrates that arc-welded machines can be good-looking



Current transformers contained in the central unit are protected from welding flash by asbestos boards which also support the current conductors.

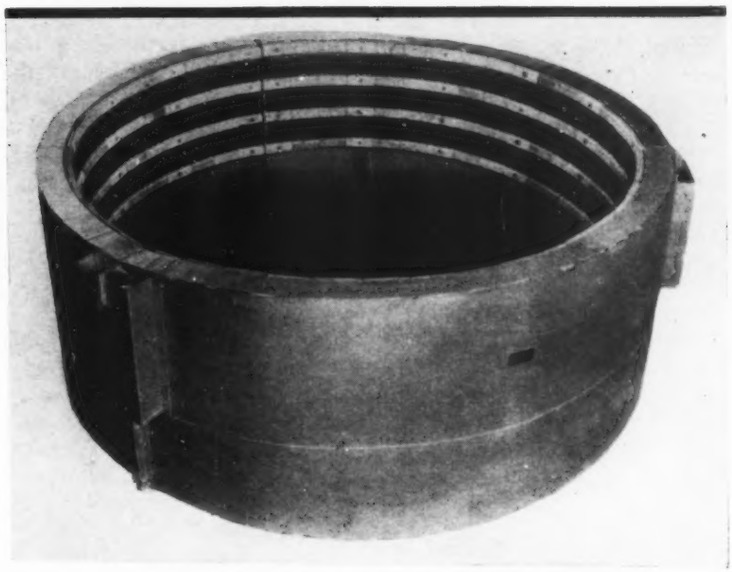
Controls in the base section govern both pressure and welding current. Application of pressure is determined by the contour of operating cams, while the pressure is adjusted by preloading springs in the top unit. Current flow is controlled by a relay closed by two fan-shaped cams mounted on the operating cams. By adjusting the relative position of the two fan cams, the time allowed for current flow is controlled. While setting up the work in the machine, the current flow can also be controlled by a pushbutton, control mounted on the head.

• *Heating Units For Low Intensity*

Uniform, slow heating of the contents of a large kettle, nearly eight feet in diameter was necessary to prevent damage to the product from localized hot spots. The electrical heater designed for this service by the Harold E. Trent Company uses almost the entire inner surface for radiation. Although the total electrical load is 45 kw. at 220 volts, the use of "folded and formed" heating units shown in the accompanying illustration reduces the heat intensity to 5.8 watts per sq.in., insuring a small temperature gradient.

Because of its large diameter, the

insulated casing is constructed in three sections for easier handling. After assembly the three sections are connected electrically to form one ring of units for each phase of the three-phase current supply.



In this kettle heater built by Harold E. Trent Company, uniform heat distribution with a low temperature gradient is obtained by closely-spaced heating units

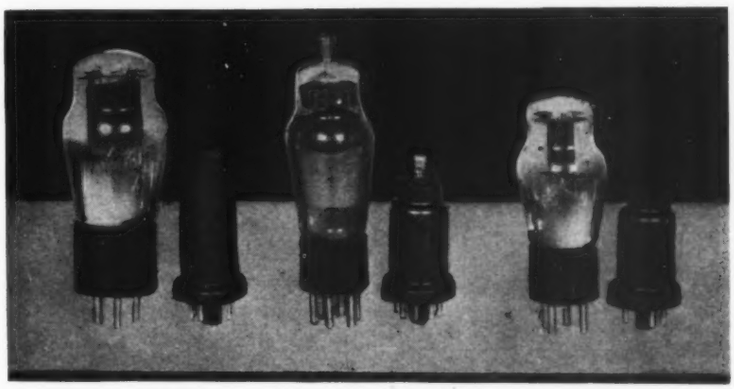
• *Metal Radio Tubes*

Nearly a billion radio tubes have been built—yet the size, shape and structure of the tube has retained features originally borrowed from the electric lamp. Glass was essential in the lamp to radiate the light. But in the radio tube, transparency is not important; in fact, a metal covering has to be added for electromagnetic shielding.

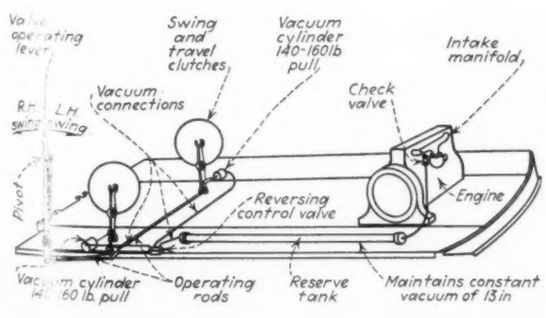
Metal radio tubes recently developed by the General Electric Company differ greatly from the conventional tube in both structure and appearance, as can be seen from the accompanying illustration. The new tubes are not only much smaller and more sturdy but offer improved electrical characteristics as compared with the conventional type of tube. The metal case which incloses the tube elements provides the shielding which in glass tubes is supplied by an added covering. Besides being a better heat conductor than glass, the metal covering is unbreakable.

In addition to eliminating the glass envelope, the new tube has shorter leads, each one brought out through a small separate seal in the base. The seal is formed by fusing a metal eyelet around the lead, using a bead of special glass. The metal of the eyelet has the same coefficient of expansion as the glass. The eyelet is resistance welded to the base and sealed by copper brazing.

After attaching the tube elements to supports welded to the base, a drawn steel shell is placed over the structure and resistance welded to a ridge formed around the base. Leads extending from the base pass straight into socket pins held in a molded insulating disk that is crimped to the steel base. The tube is evacuated through a metal tube welded to the base. After the air is exhausted, this tube is flattened and sealed by a resistance welder.



New metal tubes for radio and industrial applications are smaller and sturdier than conventional glass ones



Power from a vacuum cylinder replaces human effort in a new control system for power shovels developed by the Osgood Company

• *Power Shovel Clutches Controlled by Vacuum*

Physical effort required to operate power shovels, particularly in controlling the swing, has been one of the factors that called for husky men at the controls. But in a new control system developed by the Osgood Company no more than two pounds pressure is needed to operate the control, and the clutch engagement is said to be more positive and uniform than the action obtained from manual operation.

Power for the control system is obtained from the intake manifold vacuum of the shovel engine, utilizing power already available with no sacrifice of output from the engine. As shown in the diagram to the left, a long vacuum tank is con-

nected to the intake manifold through a check valve and a flexible tube. From a reversing control valve at the other end of the tank, pipe lines connect to vacuum cylinders developing a pull of about 150 lb. This force is used to engage swing and travel clutches.

The vacuum control valve is operated by a small lever pivoted at the top of the main operating lever. Since the main lever remains linked to the clutches, the lever motion is the same whether manually operated or vacuum controlled, allowing normal operation if vacuum fails.

• *Clutch Throw-out Yokes Hard Faced*

To reduce wear under conditions of poor lubrication, clutch throw-out yokes used in one make of heavy-duty truck have hard-faced surfaces, as shown in the accompanying diagram. Because heat generated by friction at high rubbing speed and heavy contact pressures does not soften the hard facing, the life of the new yoke is several times as long as that of a hardened steel part.

Not only is the hardness of the facing unaffected by heat, but the coefficient of friction for the Stellite is one-third less than that of a steel contacting surface. The lower friction coefficient introduces less heat from friction, further improving the wear resistance of the hard-faced yoke.

• *Redesigned for Die-Castings*

Both appearance and performance have been improved in the recent redesign of two appliances shown below—the Hobart meat chopper and the Wagner fan.

In the meat chopper, zinc die-castings and molded plastics are combined to form the housing for the motor and driving mechanism. Brushed chromium plate is used on the die-cast frame and the grinder parts. The metal stomper handle is aluminum with a black anodic finish; the plunger is drawn stainless steel.

A die-casting is used for the pedestal of the Wagner fan, giving smooth surfaces and flowing lines. But a noise-conscious public is responsible for a larger design problem—quiet operation.

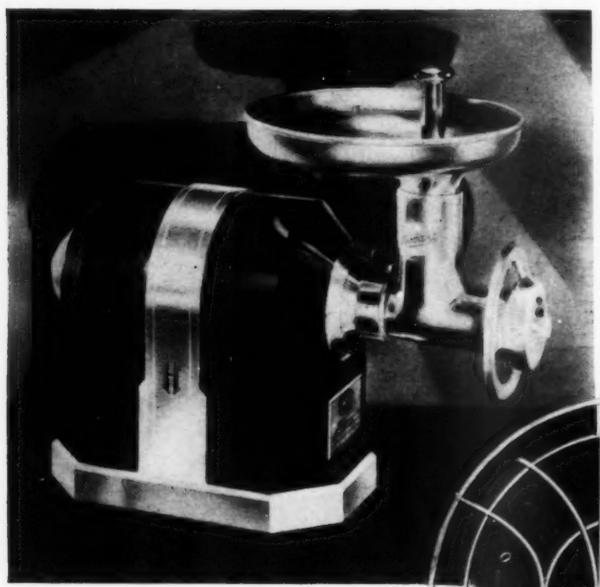
Fan noise was reduced by the adoption of an aluminum alloy blade stamped to a special contour from sheet stock. All portions of the blade surface are curved from edge to edge and from end to end, so that the air velocity is gradually increased from zero to a maximum as the blade passes through the air. With this blade contour all portions of the surface are equally effective, and the air is moved with a minimum of disturbance and noise.

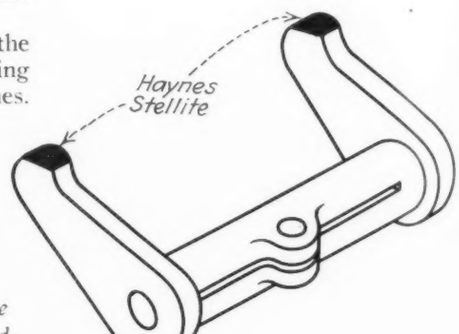
With the new blade contour, fan noise was reduced to such an extent that it became necessary to build a quieter motor.

Electrically, the design problem required the selection of the proper combination of rotor and stator winding slots as well as the proper shape of slot. A different angle of skew for the slots was required for each size of motor.

The motor shafts were designed for increased rigidity and bearing surfaces are ground and polished. Broached bronze bearings were designed with small bearing clearance, and large oil wells filled with oil-soaked wool yarn feed a constant supply of oil to the bearings.

To eliminate magnetic hum and vibration, cores are tightly riveted, and stator windings are impregnated and baked. Blades and rotors are dynamically balanced.





(Right) Stellite facings deposited by welding greatly decrease wear in throwout yokes for truck clutches

Die-castings "styled" by the Doehler Die Casting Company are used for the base of the Hobart meat chopper and the pedestal of the Wagner fan

Modern Hydraulic Control Systems and Circuits–II

HANS ERNST
Research Engineer, Cincinnati Milling Machine & Cincinnati Grinders, Inc.

How the laws of hydraulic flow that were presented in the April number are used to design hydraulic valves and circuits, those shown being patented by Cincinnati Milling Machine Company

FOR THE practical application of the equations of hydraulic flow developed in the previous article (*April P.E.*) it is necessary to establish the units of pressure, rate of flow and resistance. The conventional units of lb. per sq.in. and cu.in. per min. are used for pressure and rate of flow respectively. For hydraulic resistance, it is necessary to establish a new unit.

In order to facilitate the establishment of numerical values for hydraulic resistances, we have employed as a unit the quotient of the commonly used pressure and quantity units:

$$\text{Resistance Unit} = \frac{\text{lb. per sq.in.}}{\text{cu. in. per min.}}$$

Thus, a pump which was found to possess a "slip" of 16 cu.in. per min. when subjected to a pressure difference of 800 lb. per sq.in. (with oil of some standard viscosity such as 150 Sec. Saybolt) would be said to have a slip resistance of 800/16, or 50 units. For want of a specific name, these units are referred to merely as "resistance units."

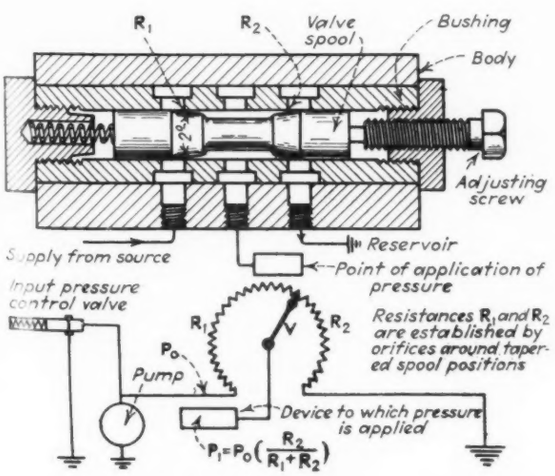


Fig. 8—Hydraulic "potentiometer," in which the movement of valve member V changes the resistances R_1 and R_2 in a complementary manner

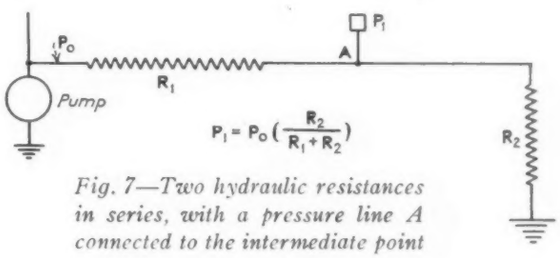


Fig. 7—Two hydraulic resistances in series, with a pressure line A connected to the intermediate point

Similarly, a choke coil which permits a flow of 5 cu.in per min. with an applied pressure of 100 lb. per sq.in. will have a resistance of 100/5, or 20 units—with oil of this viscosity.

The adoption of the "electrical" point of view in regard to hydraulic resistances and circuits leads directly to the conception of many new devices and circuit arrangements which might not otherwise readily be found. For example, with two choke coils in series, as shown in Fig. 7, leading from a pressure line to reservoir, we may take off a header line at the intermediate point A, and thus obtain a pressure P_1 which will always be a fixed fraction of the input pressure P_o. If these resistances are designated as R_1 and R_2, then the pressure at the point A will be:

$$P_1 = P_0\left(\frac{R_2}{R_1 + R_2}\right)$$

The relationship expressed by the above equation will be unchanged even with wide changes in viscosity, providing only that we are dealing with streamline flow.

Another application of the "electrical" principle is the

arrangement shown in Fig. 8, which might be termed a hydraulic potentiometer. The principle involved here is precisely the same as in Fig. 7 but the resistances R_1 and R_2 are changed in a complementary fashion by the movement of the valve member V. With this arrangement, if the input pressure P_0 is constant, any desired lower pressure P_1 can be obtained in the line A for use in valve balancing, clamping, or other operations. Obviously, the pressure in line A will only reach the value determined by the calculation indicated when no flow exists in this line.

A further example of the use of hydraulic resistance in the control of complex circuits is shown in the patented construction illustrated in Fig. 9. In multi-slide machines it is often desirable to complete the movement of one slide before initiating movement in another. This problem is made difficult by the fact that as the first slide has come to rest we may not have any moving member from which the control valve for the second slide can be operated. In the arrangement that is shown in Fig. 9, the resistance coil R is placed in series with the hydraulic line leading to the operating cylinder of the first slide. Coupled in parallel with this resistance coil is the control valve V for the second cylinder, and which is actuated in opposite directions by two plungers of unequal areas A_1 and A_2. While the first slide is in motion oil will be flowing through the resistance R, thus creating a certain pressure difference $P_1 - P_2$, but when the slide reaches the end of its stroke the flow through the resistance R will stop, and thus the pressures P_1 and P_2 will become equal. The value of the resistance R, and the areas A_1 and A_2, are made such that while the slide is moving the product of the pressure P_1 and the small area A_1 will be greater than the product of the pressure P_2 and the large area A_2. Thus the control valve V will be held in its right-hand position. When the slide has completed its movement, however, and P_1 is equal to P_2, the valve will immediately shift to the left, thus permitting the oil to pass from the supply line S to the operating cylinder of the second slide.

An example of the application of this system to machine tools is shown in the photograph Fig. 10, which illustrates a hydraulically controlled milling machine arranged for milling elongated valve clearance openings in automobile cylinder heads. In Fig. 11 is given the diagram of the hydraulic circuit.

Referring to Figs. 10 and 11, the six cutter spindles are carried by the sliding head which is moved toward and away from the work piece by the cylinder and piston *69* and *70* of the circuit diagram. Reversal of this piston *70* is accomplished by the pilot-operated reversing valve *133*, while the rate of movement is determined by the flow-dividing valve *215* under the control of the cam *141*. Maintenance of the desired feed rate regardless of the load is assured by the special balancing valve *101*. The main reciprocating table, *12*, on which the fixture and work piece are mounted, is actuated by the cylinder and piston *72* and *73*, respectively. Reciprocation of this unit is controlled in direction, and selectively with respect to rapid traverse and feed, by the hydraulically operated compound valve *76*. The valve *75* controls starting and stopping of the entire cycle.

The four pilot valves, *147*, *148*, *149* and *150*, are actuated by a series of cams, all of which are carried by a common camshaft C. These valves control the

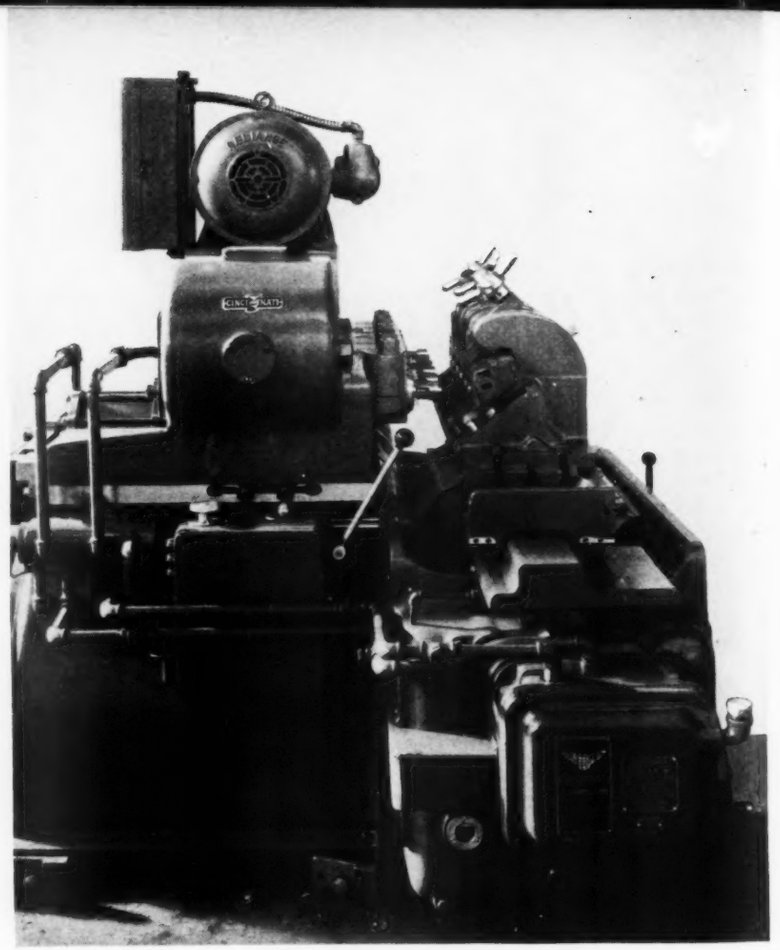


Fig. 10 (Above)—Hydraulically operated 6-spindle machine for milling elongated holes. Fig. 11 (Right)—Hydraulic circuit for the automatic milling machine shown in Fig. 10, giving sequential operation of the slides and various special controls and interlocks

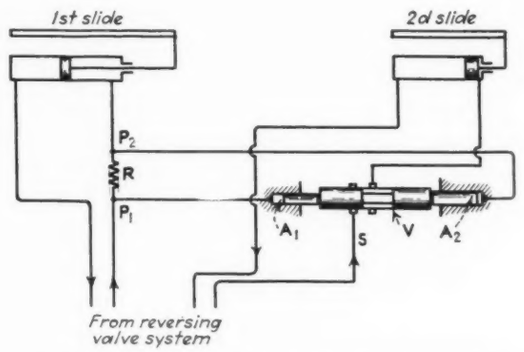


Fig. 9—Design of control valve actuated by the pressure drop across resistance R

actuation of the hydraulically operated valves *133* and *76* through the medium of the operating plungers *161, 163, 168, 170, 173* and *175*. Plungers *168* and *170* move the valve *76* axially, while plungers *173* and *175* cause a change in the valve connections by an oscillation about the axis of the valve.

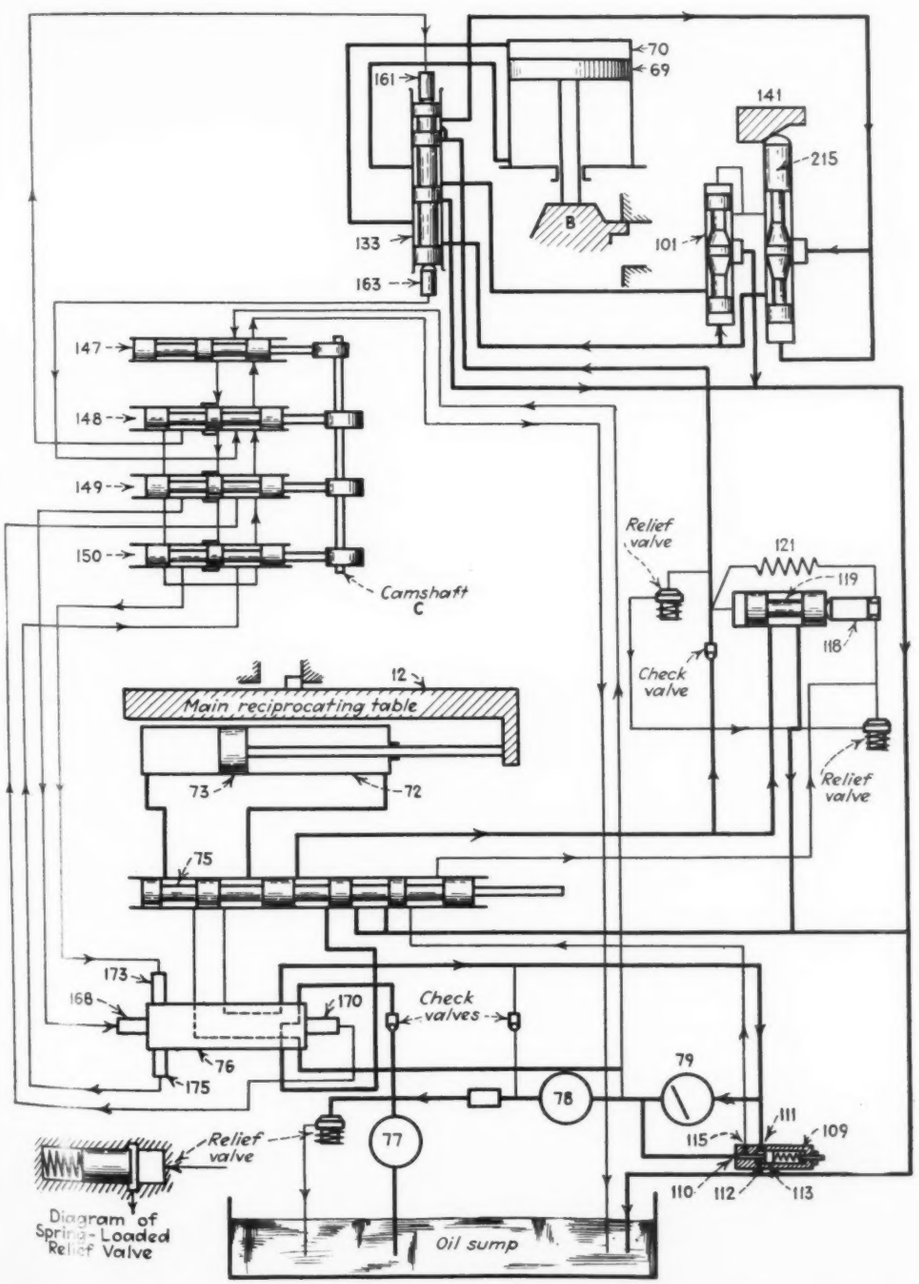
Member *77* is a large low-pressure, constant displacement pump, the principal function of which is to provide the large volume of flow needed for rapid traversing. This pump is also employed to supercharge the small high-pressure constant displacement pump *78*, which, in conjunction with the variable displacement pump *79*, is used to provide the feed movement of the piston *73* and table *12*. The feed system used is of the type known as "locked" circuit, the rate of movement being determined by the quantity of oil permitted to escape from the outgoing end of the cylinder *72* through the variable displacement pump *79*. The excess fluid discharged by the pump *78*, over and above that volume necessary for the building of forward pressure in the ingoing end of the cylinder *72*, and that required to make up for the cylinder differential introduced by the piston rod, is permitted to escape through the special pressure control valve *109*. Valve *109* is of the type known as a differential valve, in that the operating pistons *112* and *113* are acted upon by two independent pressures in lines *110* and *111*. Thus the valve acts to provide at all times a desirable relationship between the value of the operating pressure in the ingoing end of the cylinder *72* and the working load.

The principle of operation of the valve system *118* and *119* and the resistance *121* has been described and shown diagrammatically in Fig. 9. In this application this valve system is used to initiate the movement of auxiliary slide *B* which must move in sequential relationship to main slide. That is, this system is used to initiate the movement of the table *12* after the piston *70* has reached the end of its stroke as determined by the stop.

Control valves in modern hydraulically operated machines are usually of the piston or spool type, the connections between adjacent ports being made by the spaces between the spools or "lands" of the valve; the ports consisting either of grooves turned in the surrounding valve chamber, as shown in Fig. 12 at *A* or else consisting of radially drilled holes connected by an annular groove in a surrounding bushing, as in the arrangement shown at *B* in Fig. 12. For free operation, it is essential that the valve be balanced with respect to the applied pressure. This can readily be done in the case of piston valves as shown in both of the above constructions. In fact, the ease with which a piston valve can be balanced is largely responsible for the present common use of this type, as compared with the rotary plug type of valve formerly used in hydraulic systems.

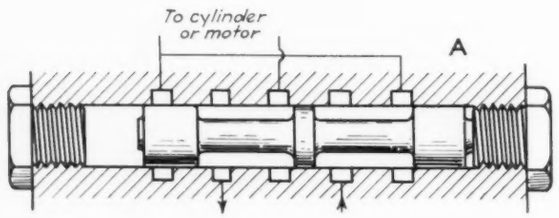
In most modern circuits the reversing valve is pilot operated. This has the advantage of permitting the use of a small light pilot valve that can be readily operated either by hand or by dogs carried by the moving slide. Furthermore, the rate of movement of the reversing valve may be controlled by the rate at which the oil is permitted to flow to it from the pilot valve. It also permits the provision of any desired delay in the operation of the reversing valve subsequent to the tripping of the pilot valve.

In the early applications of hydraulic power to machine slides, much difficulty was caused by the inclusion of air in the system. This condition is now well understood and in modern hydraulic systems



there is little reason for trouble on this account. In this connection, the old adage "prevention is better than cure" is particularly appropriate. Thus, every effort should be made, both in the design and construction of the system, to prevent air being taken in. The obvious places where such precautions should be taken are at points in the system where sub-atmospheric pressure occurs, namely, in the suction line leading from reservoir to pump, and at any possible point of entry to the intake chambers within the pump. To reduce this hazard, suction lines should be as short in length and as large in diameter as possible and wherever convenient the pump itself should be submerged.

In practice it frequently happens that air is drawn into the hydraulic system at points which would ordinarily seem most unlikely, namely in the return lines from the system to reservoir. In such lines, however, the pressure is usually quite low. Thus, at sudden changes in section, or in direction of flow in the line, as at pipe fittings and corners, local points of sub-atmospheric pressure may occur. Should there be a slightly loose fitting or opening at such a point, air will be drawn into the system. Where branch lines must lead from a reservoir return line, as for example for the lubrication of working parts, a low pressure



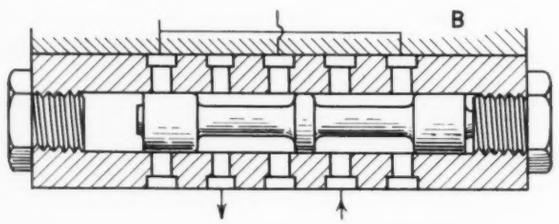


Fig. 12—Alternate designs of piston type reversing valve

relief valve or other restriction should be provided close to the point where the return line enters the reservoir, thus maintaining a definite low pressure throughout the return line and preventing the induction of air in this manner.

Another important point which should be observed in this connection is to carry all return lines into the reservoir well below the surface of the oil. Failure to do so frequently results in the formation of vortices in the neighborhood of the return line, thus causing air to be mixed with the oil in the reservoir. This mixture of air and oil will enter the system through the pump intake. To minimize trouble from this source, the pump intake should always be placed as far as possible from the point where the discharge lines enter the reservoir.

In addition to the precautions for preventing air from entering the system, means should also be provided to prevent accumulation of air within the system. It is a well demonstrated fact that oil may carry relatively large quantities of air in suspension in the form of minute bubbles, sometimes so small as to be invisible to the naked eye. While the oil is maintained under pressure, these bubbles may stay in suspension, but if the pressure is reduced they increase in size and separate from the oil in a manner similar to the separation of CO_2 from carbonated water. Thus, in a hydraulic system there is a tendency for air to separate from the oil and collect at high points in cylinders and pipes.

The most satisfactory way yet found for the elimination of air from high points in the system is by means of "bleeder coils" or high resistance outlets permanently connected between such points and reservoir. Owing to the great difference in viscosity between air and oil, the air will readily be expelled through such outlets while the quantity of oil which escapes thereafter is negligible. To facilitate this action, the ratio of the length of bleeder coil to its diameter should be great. This permits the use of relatively large bore tubing, and consequent freedom from clogging with foreign matter. In practice it has been found that air bleeder tubes of 0.054 in. bore are virtually immune from such clogging, providing that the inlet ends thereof are connected to points adjacent to the upper walls of the chambers from which the air that has accumulated is to be eliminated.

In some applications, where extreme smoothness of movement at low speeds is not essential (particularly when the machine is first started) air bleeders from the operating cylinders may be dispensed with, providing that the design is such that the intake and exhaust ports are located close to the upper surface of the cylinder. In this way any large accumulations of air will be washed out as the oil is discharged from the outgoing end of the cylinder.

The application of hydraulic power to machine movements is still in its infancy—with each new development in control mechanism, the field is broadened. Whereas a few years ago we were accustomed to thinking of hydraulic power only when brute force was required—as in heavy presses—we now see its usefulness in the operation of highly sensitive mechanisms. Sensitive valves may be made to control the motion of ponderous slides by movements of less than 0.001 in., and an almost unlimited assembly of motion-producing or motion-preventing devices can be arranged and interlocked for safe automatic operation by proper circuit design.

As in all designing, there are numerous detail problems that must be worked out properly if the machine is to function satisfactorily. In the design of hydraulic systems these include, in addition to the items mentioned above, the details relative to the design of the hydraulic cylinders. The forces and velocities required for the operations must be determined and the hydraulic cylinder diameters must be calculated to give the required force at the desired unit hydraulic pressure. Proper attention must also be given to the design of the hydraulic packings, stuffing boxes, glands and all of the other mechanical details that enter into the problem.

Hardness, fatigue strength, conductivity, ductility and stability in these beryllium-copper parts are controlled by heat-treatment and cold work in fabrication

Established Properties And Proved Applications of

Beryllium Copper

ROBERT W. CARSON
Assistant Editor, Product Engineering

SINCE 1932 when the material was first announced in *Product Engineering*, the unusual properties of beryllium copper have led to a number of applications—many successful and some disappointing. Over-enthusiasm and insufficient physical data in some instances led to failures. Today, however, the available data and information on physical properties and heat treatment is more complete, and successful applications are found in a wide variety of products.

But each successful application has required a design based on the physical properties that are characteristic of the material as well as knowledge of the effect of heat-treatment on these properties. In no design has the problem been solved merely by substituting beryllium copper for another material.

In contrast with the quench hardening required for steel, age-hardening of the 2.25 per cent beryllium copper requires quenching from 1,475 to 1,500 deg. F. and reheating to a temperature of 500 to 600 deg. F. for one hour or longer. During this age-hardening heat-treatment the hardness and strength increase rapidly during the first few minutes, reaching a maximum within one to five hours. While being heat-treated, elongation decreases as the hardness increases reaching a minimum value of about 2 per cent. Higher heat-treating temperatures result in maximum hardness being obtained in a relatively short time, and continued heating causes a reduction in hardness along with an increase in ductility. At low heat-treating temperatures longer time is required to reach maximum hardness, and continued heating for an extended time may introduce no softening. In addition to requiring a longer time, low temperatures give a lower hardness.

The amount of cold work in the material likewise influences the effect of heat-treatment, additional cold work increasing the maximum obtainable hardness and strength. But with a greater degree of cold work, the aging or hardening proceeds at a more rapid rate, giving maximum hardness when heat-treated at lower temperatures for a shorter time. Thus, to obtain maximum hardness, three factors must be considered: cold work in the material, heat-treating temperature, and length of time that the material is held at the heat-treating temperature.

The change in tensile strength during heat-treatment is proportional to the change in hardness but the effect of heat-treatment on other properties such as endurance limit, ductility, stability or creep, electrical and thermal conductivity is not necessarily the same. Higher fatigue strength and greater ductility are obtainable by heat-treatments that do not reach maximum hardness. Stability or resistance to creep at normal temperatures

is obtained only with complete relief of internal stresses, requiring heat-treatment above the point of maximum hardness. For maximum electrical conductivity the material must be heat-treated at a higher temperature for a longer time than is required for maximum hardness. With over-treatment electrical conductivity increases to more than 37 per cent that of copper, although the strength is reduced to about 135,000 lb. per sq.in. Over-heat-treatment beyond the point of maximum hardness also increases the thermal conductivity to more than 40 per cent that of copper with some decrease in hardness and strength.

The heat-treatment used for any application therefore must be selected with reference to the most important properties needed. But it is because of this wide range of possible physical properties that beryllium copper can be adapted to a variety of applications.

In the design of springs, such factors as strength, ductility and shock resistance can be varied by cold work and heat-treatment to give either maximum endurance strength, maximum hardness, minimum creep or maximum conductivity, whichever may be the most important factor. Where heavy draws are necessary, as in the bellows shown here, the forming operation can be performed on annealed tubing and the desired strength introduced by heat-treatment after forming. In parts requiring forming, intermediate anneals can be used to reduce drawing difficulties, while the elimination of internal stresses during final heat-treatment increases the endurance strength.

In beryllium-copper bellows subjected to extreme cold work in forming, the desired high strength can be introduced by heat-treatment alone

In combination with its high strength, the wear resistance of beryllium copper gives this material excellent bearing qualities. In the hub bearing shown above, used in controllable pitch propellers made by Pratt & Whitney, the high strength of the beryllium copper allows the use of bearing pressures greater than 4,000 lb. per sq.in. Although the bearing rotates only 8 deg., severe vibrations and high bearing loads had caused other materials to fail in a relatively short time. With beryllium-copper hubs having 380 Brinell hardness and a chrome-molybdenum steel shaft hardened to 410 Brinell, no scuffing or wear is found after more than 3,000 hours of service.

When used for worm gears, beryllium-copper blanks are accurately and easily machined in the annealed condition and after hardening not only possess excellent wearing qualities but also high strength, and high resistance to shock loads. In one application on a textile machine, beryllium-copper worm gears have shown no signs of wear after eight months in service, although the life of bronze gears previously used was no more than three or four months.

Good wearing properties of beryllium copper increase the service life of Pratt & Whitney controllable pitch propeller hubs. Tests on watt-hour meter bearings with beryllium-copper inserts (left) show a life of several years without lubrication

Bearings for watt-hour meters also require high hardness to give them a long life. In one type of bearing shown here, using a single ball between spherical cups, tests now being conducted indicate that beryllium-copper bearings will operate with low friction for several years without lubrication. In contrast with sapphire ordinarily used for such applications, beryllium copper can be machined, formed and polished in the soft, annealed condition, with the required hardness obtained by heat-treatment after machining.

In other electrical devices beryllium copper is being used because it not only has the strength and hardness of steel, but also is non-magnetic. Although contact springs can be worked at stresses ordinarily used for steel springs, the elastic modulus of the copper alloy is lower than that of steel. However, beryllium-copper springs have the added advantage of easier soldering, and the springs can be formed accurately to shape before hardening. Service experience with the contactor shown here, made by the Electric Tachometer Corpora-

tion, shows that beryllium-copper springs have a fatigue strength equal to that of spring steel and much higher than phosphor bronze.

When used for contacts requiring low electrical resistance, heat-treated beryllium copper shows much higher strength at elevated temperatures than cold-worked phosphor bronze. Service conditions involving temperatures as high as 350 deg. F. have little permanent effect upon the tension of stressed springs. In fact, subjecting the material for an extended time to such a temperature may result in an increase in strength. These advantages in combination with its low electrical resistance led to the adoption of beryllium copper for contact clips made by the Fahnstock Electric Company for use on high-current rectifier bulbs. Whereas other materials failed within a few weeks, beryllium-copper clips have now been in service for more than a year without a failure.

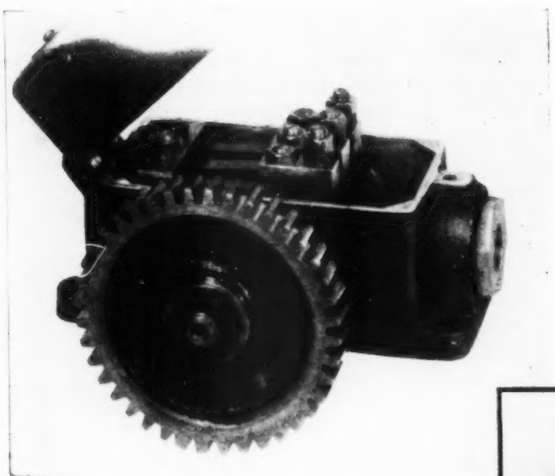
From tests conducted by the author over a period of four years, a sensitive method of measuring elastic properties has brought to light several interesting facts concerning heat-treated beryllium copper.

In addition to high strength and resistance to wear and heat, beryllium copper also has a greater stability, or freedom from drift, creep or hysteresis, than worked-hardened materials. In many spring applications requiring precise deflection rates, creep effect rather than tensile strength limits the allowable working stresses. For precision springs, the stability of heat-treated beryllium copper makes possible the use of working stresses much higher than can be used with phosphor bronze. The spiral instrument springs shown below, made by Precision Products Company, not only have good formability and corrosion resistance equal to phosphor bronze, but also have lower creep, higher elasticity and lower electrical resistance, and because of the high strength of the material these springs hold their shape better.

For such parts as instrument springs, diaphragms, bourdon tubes, bellows, and other calibrated spring members, the stability of beryllium copper at higher stresses allows the design of smaller, more compact springs, with an accompanying reduction in elastic defects. Although relatively high stresses can be used without introducing serious creep effects, the lower elastic modulus of the copper alloy requires a larger cross-section or a shorter spring for the same deflection rate. However, beryllium copper is non-magnetic and resistant to corrosion—important considerations in many instrument applications.

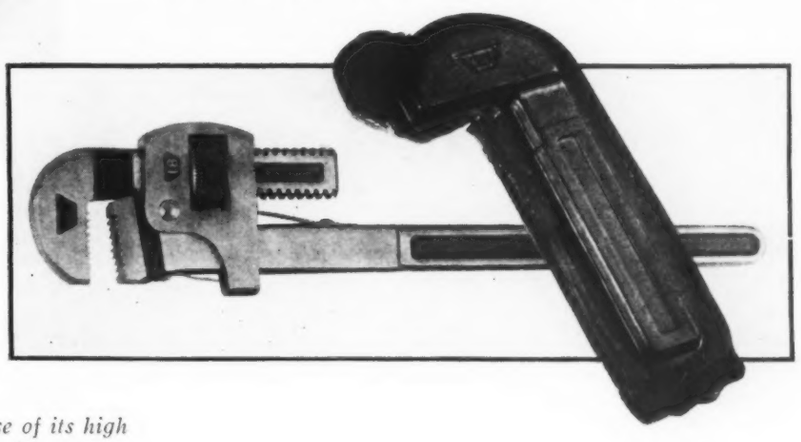
In addition to being non-magnetic, beryllium copper is non-sparking. In the hardened state its strength and resistance to wear and corrosion makes possible the use of this material for hammers and blades in grinding mills, pulpers, and mixers. Hand tools such as chisels, hammers, scrapers, or wrenches are made of beryllium copper for use in explosive atmospheres. Tools such as the Stanley pipe wrench illustrated can be forged in the same dies designed for steel if proper attention is given to the forging temperature, and allowance made for the slower flow characteristics of the alloy.

Handles for surgical instruments made of beryllium copper are stiff, strong and easy to chromium plate, according to the Bard Parker Company. Warping experienced with hardened steel handles is not introduced in the precipitation hardening treatment. In addition, parts having an intricate design or complicated shape can be forged easily from annealed beryllium copper. When heat-treated, the forgings have the desired strength, hardness and corrosion resistance.

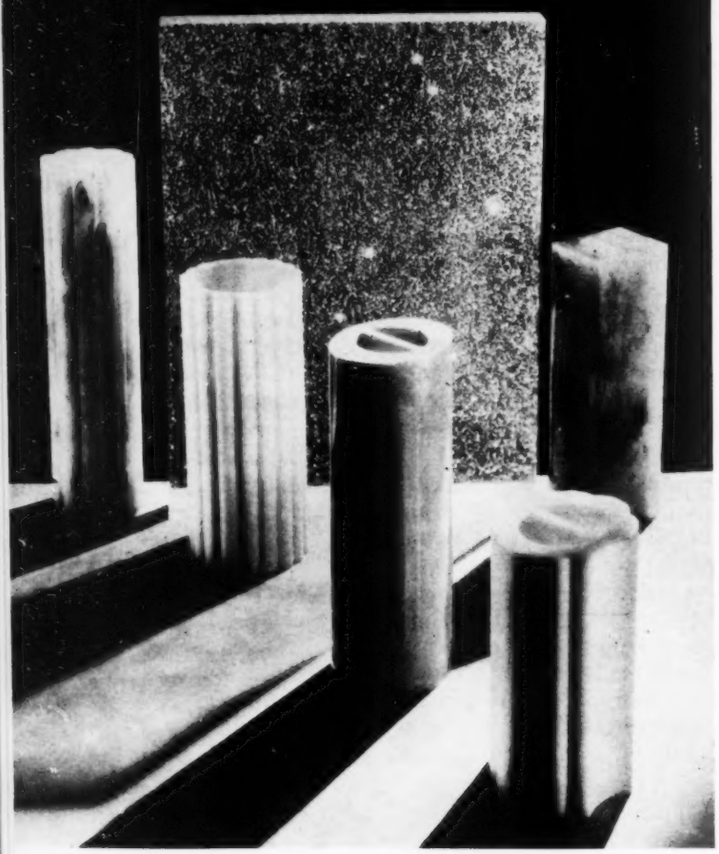


Beryllium copper for electrical contact springs in the Electric Tachometer contactor combines high conductivity and good fatigue strength

Beryllium-copper forgings for non-sparking Stanley wrenches are made in the same dies used for steel parts



Because of its high electrical conductivity and resistance to creep, beryllium copper is used for instrument springs made by Precision Products Company



Examples of Catalin. Block at the rear has flakes of silver cast within it, producing a beautiful sparkle

Plastics for the decorative effect

HERBERT CHASE
Mechanical Engineer

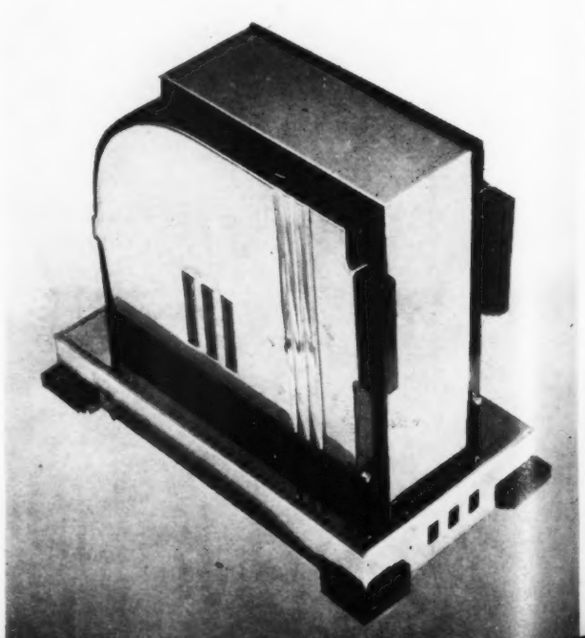
PLASTICS have well established their utility as materials of construction. They are now rapidly coming into their own as decorative products and today are often employed for making a complete product. But more frequently, perhaps, plastics are combined with other materials with pleasing results, not to mention noteworthy increases in the sale of the product. In many instances plastics displace wood, partly because of better lasting properties. In others they take the place of metals, but are more often employed with metals to the advantage of both materials as well as with improvement in appearance.

From a decorative standpoint it is well to remember also that plastics often take the place of such materials as glass, many of the semi-precious stones, amber, quartz, mica, shell, marble, ivory, onyx, certain ceramics, jade and a wide variety of other materials. They do not possess all the qualities of these materials, but have superior qualities in many respects and can be had in a wider range of colors. Most of the plastics are available in translucent form and some can be had in translucent and crystal-clear form almost rivaling glass in this respect. Often transparency or translucency adds to the beauty and depth of color and provides effects which either cannot be duplicated by other materials or cannot be duplicated at a price to make it commercially feasible.

To the appearance qualities must be added the excellent physical and chemical properties, such as ample strength, both mechanical and dielectric, lighter weight, pleasant feel, resistance to atmospheric corrosion and many other deteriorating factors. Many of the plastics possess toughness or comparative freedom from brittleness, besides many other useful properties. It is small wonder that the engineer as well as the artist is putting plastics to uncounted uses.

For exposed parts, in which decorative effects are of greatest importance, as well as for some parts in which appearance is a secondary consideration, the plastic usually has at least one outstanding advantage which mechanical designers accustomed to working with metals often overlook. Plastics require no applied finish; their color goes all the way through and seldom changes in service. Plastic parts come from the mold, as a rule, substantially ready for use. Nor is there the expense of polishing or chemical cleaning before finishing or of plating or enameling, such as generally required for exposed metal parts. At first thought these may seem to be minor considerations, but it is often true that with other materials the finishing costs are from one to three times as much as the cost of the unfinished piece. In a large group of products the cost

Modern toaster with molded Bakelite base which makes a pleasing contrast with the nickel-plate



of finishing is the chief reason for using a plastic in preference to some other type of material.

Before dealing with specific applications of plastics, it may well be pointed out that it is not necessarily true that mold costs will be involved if a plastic is used. It is true, of course, that a mold is required if a molding plastic is selected. Today, however, some of the important plastics are not molded. Several of these are available in rod, tube or sheet form, and others can be cast close to actual size with only a small investment in a "form," which corresponds to the pattern used in making the mold for metal castings. Such cast phenolics include Catalin, Marblette, Joanite, Ivalure, Fiberlon and certain forms of Bakelite, and are produced chiefly in forms intended for machining, like wood or metal, on any of the common metal-working tools. The same is true of some other plastics, such as nitrocellulose and cellulose acetate types, and the latter, as well as the cast phenolics, can be formed or shaped under certain conditions.

Cast phenolics have gained wide use within the last few years because of the beautiful forms in which they are available, their moderate cost as compared to certain other plastics and the ease with which they can be turned, sawed, carved, polished and worked in other ways. They are available in any color, in many mottled effects, in any degree of transparency or translucency, and are easily cut or formed into handles, feet, knobs, bases, fronts and a wide variety of other decorative parts with little or no cost for tooling. If a variety of colors are needed to fit the same product into different environments, it is merely necessary to buy the rod or other stock in these different colors. As machining leaves a dull surface, polishing, or "ashing" as it is termed, or tumbling in a polishing medium is required, but no applied finish is needed. The cast phenolics are thus often employed where moderate quantities are needed and the cost of a mold is not justified. They are also used for parts made in large quantities.

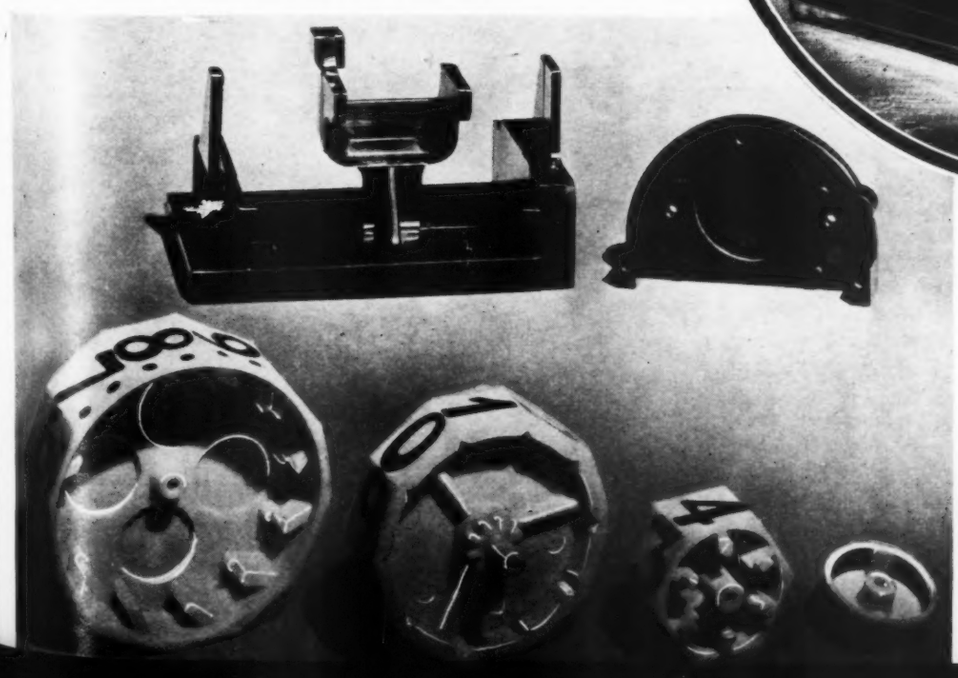
Such parts as handles for kitchen utensils, cutlery, umbrellas and the like are often cast from the phenolic resins to approximate size and shape in special molds made on forms of substantially the same shape as the finish part. These forms are dipped in molten lead. The resulting lead mold, when stripped from the steel form, is used for casting the liquid resin, which latter is cured in an oven. Cast parts thus made require little or no machining except perhaps for drilling and removal of flash, and they are then ready for polishing and application to the metal part. Occasionally glass molds are employed in casting, in which case even the polishing can be dispensed with because of the extremely smooth surface which the glass mold presents.

As the cast phenolics are quite resistant to heat and to most other common deteriorating factors, are non-inflammable and available in many of the colored effects formerly obtainable only in nitrocellulose or cellulose acetate, and in general are lower in price than the cellulose products, they have displaced the latter in many, but by no means all applications. Several of the makers of cellulose products are now also producing cast phenolics, though as yet the chief producers specialize in this type alone.

Reference to accompanying illustrations gives an idea of some uses of cast phenolics. When employed for handles for cutlery or kitchen utensils, the cast piece is polished, drilled, heated in a hot solution and

Barrett figuring machine in which the case is molded from Durez and embellished with a sphere of Catalin for the recording lever handle

Clock parts molded from Plaskon, the ivory color of which makes the black numerals stand out clearly



pressed on the metal shank. Upon cooling it shrinks fast to the shank and if the operation is properly performed, no cement is required. The Washburn Company is among those who have found Catalin handles not only highly successful but a great asset in the sale of their "Jewel" line of kitchenware. As compared to cheaper wooden handles, there is no applied finish to chip or wear off, and the translucency of the cast phenolic handle gives it a quality look not easily duplicated, with equal cost and serviceability. A jade green, slightly mottled, has been found the best color for kitchenware, but some red and some yellow is used. One of the Washburn sets of kitchenware combines the Catalin with Monel metal parts, which, of course, never corrode.

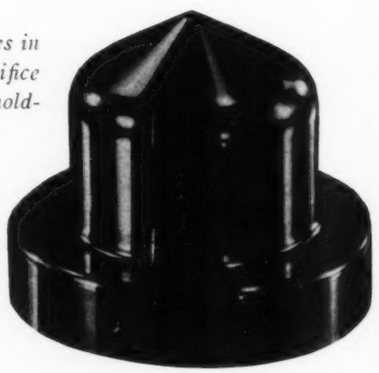
Catalin and other cast phenolics have found wide use in automobile hardware and accessories, some parts being used even in outdoor exposure. Cast phenolics are also used for furniture hardware, lighting fixtures, clocks of many makes and types, for handles of decorative parts on electrical and similar household appliances. They are used on display and advertising fixtures, on table, smoker's and desk accessories, on some business machines, in games and sporting equipment, and on a wide variety of novelties and costume and other jewelry, often in combination with metal parts.

All this does not mean that the molding plastics have lost ground, for quite the reverse is true. Molding phenolics, ureas, and acetates continue to gain in popularity and nitrocellulose still retains its place as one of the most important plastics. All of these materials find wide use in sheets, including laminated forms, in addition to their application in molding. In thin sheets, nitrocellulose is still supreme, but cellulose acetate is rapidly gaining and vinyl acetate is not to be overlooked. Still newer plastics are being or are about to be introduced but have yet to gain much commercial importance.

Sheet plastics of many kinds are extensively employed today to improve the appearance of a large range of items in which the product engineer has a hand. They have entered the modern railway coach for window sills and table tops. They are found in the ocean liner, where their use in partitions is a fire-retardant, as well as a means of beautifying and of offering resistance to the effects of cleaning compounds. They are used in refrigerator construction and as table tops in both metal and wood furniture. Pyralin and Celluloid sheets find wide use in such diverse products as fishing reels and lures, glare shields, musical instrument parts, toilet ware, games of several types, pocket and other knife handles and a variety of bathroom fixtures, to mention only a few applications. Availability in beautiful pearl-like and other attractive colorings is, of course, a primary asset, but ease of forming and enduring qualities are not to be overlooked.

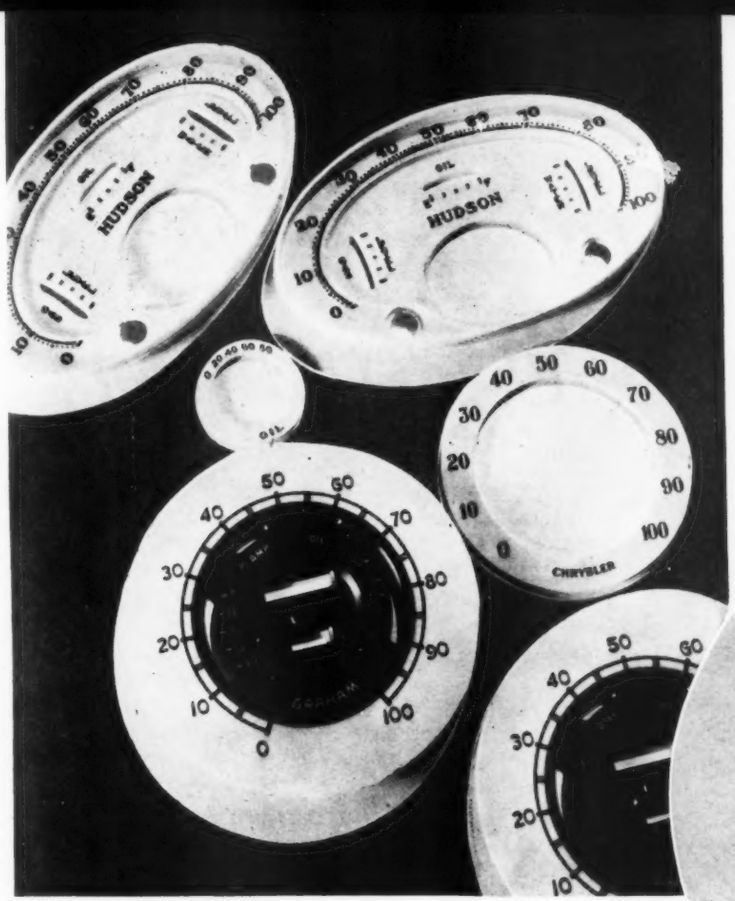
Acetate sheet is used for many of the same purposes as nitrocellulose and often takes the place of the latter when slow-burning properties are needed or where the hazards of fire must be avoided. Nitrocellulose also has a wide and important use for spectacle frames and goggle frames, but acetate is also used in the latter as well as in other optical goods. Acetate is also excellent for molding in powdered form and is gaining ground for a variety of molded articles, especially where transparency or translucency or unusual toughness is needed. It is an excellent dielectric and has been employed to good advantage, both from an appearance and utility angle for screwdriver and other tool handles, as well as for office machine keys, to mention only a few uses.

Phenolic moldings are so widely known and so excellent for a wide variety of decorative and other uses as to require little emphasis. Perhaps 75 per cent of such moldings are in black, and there is no more fitting or useful "color" in many surroundings. When brighter colors are needed they can be had, though usually at a somewhat higher price. Black with polished metal continues popular, but recent reports indicate that a bright red has increased sales in some classes of product, especially for knobs and handles, whether molded phenolics or other plastics are used. Black for the bases on toasters and other electrical appliances give a substantial and pleasing appearance that has led many designers to specify it. Molded housings for motors and for portable tools and other



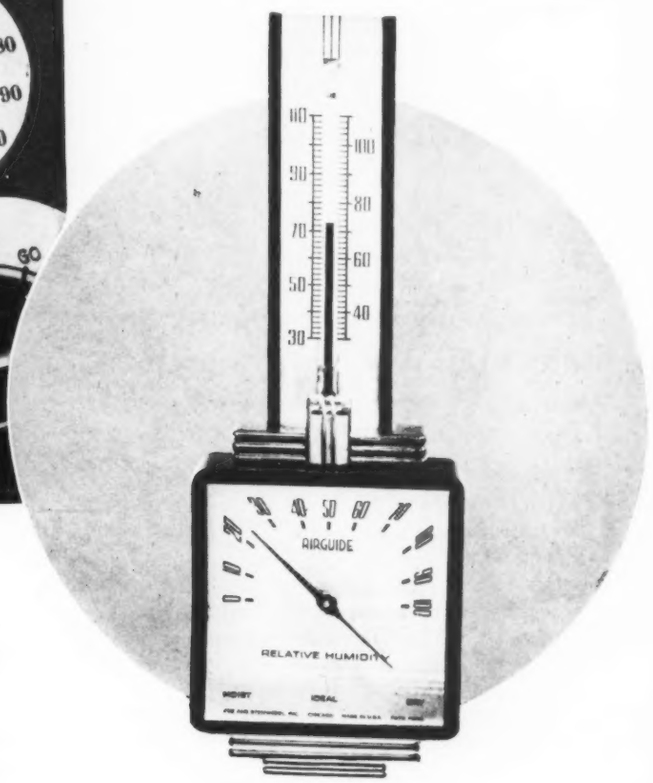
Highly finished surfaces in this Durez metering orifice are obtained in the molding operation

Durez pocket case molded by Norton Laboratories has a polished surface to avoid catching grease and dirt



Dials of Plaskon, light in color and translucent, are read easily by reflected or transmitted light

The plated die-castings and the case of molded Bakelite lend character and distinction to the Airguide



devices are now often made from phenolic compounds. Their fine appearance, light weight and freedom from the need for an applied finish are among the important advantages.

Moldings from urea compounds, which include Plaskon, Beetle and Unyte, have also made rapid advances, especially where translucency, which this type of material possesses, is an asset. These materials are available in pure white and light tints and are most generally employed in these colors, which they hold without darkening under light exposure. Important uses have been recorded in automotive applications such as instrument dials and dome or other light covers where the translucency and lack of fragility are important considerations. Many beautiful clock cases have been molded from such materials and in one instance much of the mechanism, in the form of number wheels, was molded from Plaskon in an ivory color. Lighting fixture globes and globes for gasoline pump cap lights have also been molded from the same material to avoid the high breakage which occurs when glass globes are handled and exposed to heat from within and rain or snow from without.

Striking effects can be obtained when plastics are combined with metals having a bright finish. This may be simply a polish as on nickel silver and similar non-tarnishing alloys, or the metal may be nickel or chromium plated, as in toasters, percolators and similar electric devices for the home. By using a dark colored plastic in combination with bright metal trim, pleasing contrasts are procured. And with striped metal edgings, not only is appearance improved but metal framing also increases the strength and prevents chipping.

Smooth unbroken surfaces can often be obtained with molded plastics whereas another type of construction might require projections. Thus, the molded plastic part can be attached by cast-in studs, the nut being screwed on from behind. Or the nut may be cast into the molded part which is then held by a machine screw inserted from the other side of the panel or part to which the plastic piece is to be attached. In this manner the fastening means are hidden.

An unusual method of getting striking effects is the use of prefinished stamped sheets in combination with molded plastics. The metal sheet is stamped to the desired shape with suitable designs if desired. The stamping is then put in a mold and transparent plastic molded around it. When finished the stamping is covered with transparent plastic, has a glossy finish and is protected.

Scores of illustrations of the decorative effects produced with plastics might be cited. Engineers find their utility increasing and their decorative value excellent. For the artist skilled in designing for industry, plastics offer amazing possibilities. No other material is so versatile nor so flexible as the phenolics and ureas in their various forms. The heat and electrical insulating qualities of plastics makes them ideal for modern kitchen equipment and their use increases the life and utility of the utensil in definite ways. The finish never changes or wears out.

Lubrication for Bearings That Seldom Get Attention

Provisions for bearing lubrication should be so simple that bearing maintenance and replacement is reduced to a minimum. This article shows how some engineers have solved this problem in various ways

IN THE design of machines there is a definite trend to use bearings that need no further individual lubrication after the machine has been assembled. For this purpose pre-lubricated anti-friction bearings, the oilless type of sleeve bearing and automatic lubrication are used. The problem of positive bearing lubrication may be divided into five major divisions: (1) Where assurance of lubricant is paramount under various conditions, as in airplanes. (2) Where complete sealing is required, as in construction machinery. (3) Where the lubricant would be dissolved or washed away. (4) Where lubricating is liable to be overlooked, as in household appliances. (5) Where the bearing is in an inaccessible location or when the labor of applying the lubricant is a cost factor.

In some instances a combination of these requirements is necessary for dependable service, as in aircraft design. The chief engineer of a leading airplane and motor manufacturer makes the following suggestions: "We are particularly interested in the pre-lubricated, sealed-in ball bearings of small sizes. (Figs. 1 and 2.) The loads in an airplane control system are not large but it is essential that they should work without fail at all times. We are interested in this type of bearing because of the importance of weight in airplane design. To save the weight of inspection doors, windows and removable panels, it is essential that we should be allowed to bury these bearings completely inside the structure with no attention to them for a year or two."

Another airplane company reports that oilless or graphited bearings are used in numerous locations where lubrication is difficult or uncertain. In some instances oil under pressure is fed to this type of bearing which replenishes the lubricant initially supplied.

To assure proper lubrication, adequate sealing must be incorporated into the bearing design. A. C. Rasmussen, chief engineer of the Insley Manufacturing Company, builders of construction machinery, states: "The problem of sealing a bearing always exists in construction machinery which operates in mud and dirty water or which is exposed to splashes of wet concrete. By virtue of these adverse conditions, the problem of keeping dirt out of the bearings is of equal importance to that of keeping the lubricant in the bearings."

In some commercial bearing seals, the leather sealing member, which is oilproofed, is adjusted for size and wear by a garter spring. Another type of bearing seal for high-speed work has an oil and waterproofed diaphragm type of seal made of fabric and backed by a series of small compression springs. These various seals are claimed to withstand temperatures greater than 200 deg. F. and surface speeds in excess of 3,000 ft. per minute.

Where bearing sealing members are not provided, as in the Wayne gasoline service station pump, shown in Fig. 3, a bearing which requires no lubrication must be used. Because any lubricant applied to the bearings would be dissolved by the gasoline in which the bearings are submerged, oilless bronze bearings of low lead content are used. A similar bearing is used in the metering device of the same pump. Where the bearing loads are not severe, as in the computer mechanism, oilless bronze bearings of high lead content are used.

Where there is danger of the lubricant being washed out of shielded ball bearings, the chief engineer of an

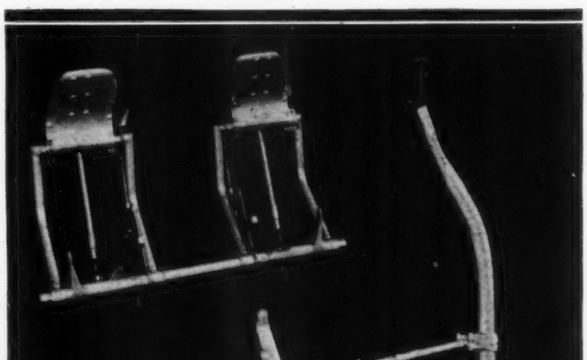


Fig. 1—In airplanes, rudder and brake pedal (left) and control stick assemblies (right) must operate smoothly at widely varying temperatures

airplane engine company says: "Of late we have found that the present type of ball bearing with a stainless steel cover for sealing it is not a satisfactory answer for airplanes which are continuously operated on salt water.

"The difficulty is not with conditions which could be tested by means of a salt spray, but with the actual drenching of salt water which occurs during take-off and landing. The lubricant is washed out of these bearings in this kind of service, and as a result, the bearings become corroded, which causes them to turn as a unit on the shaft rather than to function as they should. This condition is dangerous if it is not found in time. It is probable that the only solution to this difficulty would be the use of stainless steel throughout, both for balls and races, which at the present time has the disadvantage of lower allowable bearing capacities and higher cost."

Fig. 3—In the Wayne Company's service station pump, the bearings are submerged in gasoline. To overcome corrosion an oilless type of leaded bronze bushing is used

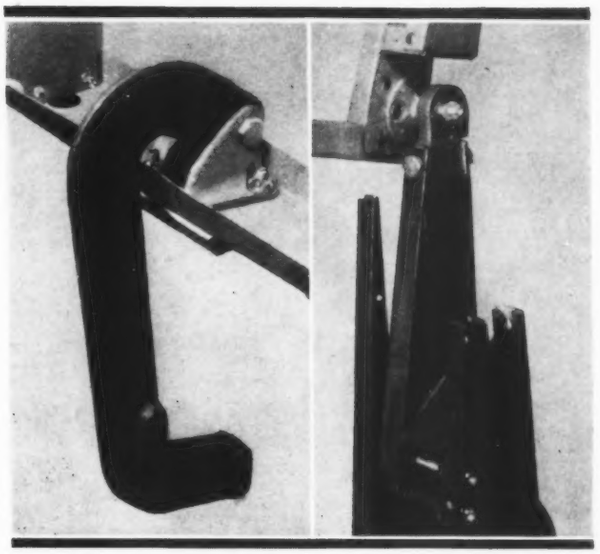


Fig. 2—For inaccessible hinge locations, the use of sealed pre-lubricated ball bearings make hand lubrication unnecessary

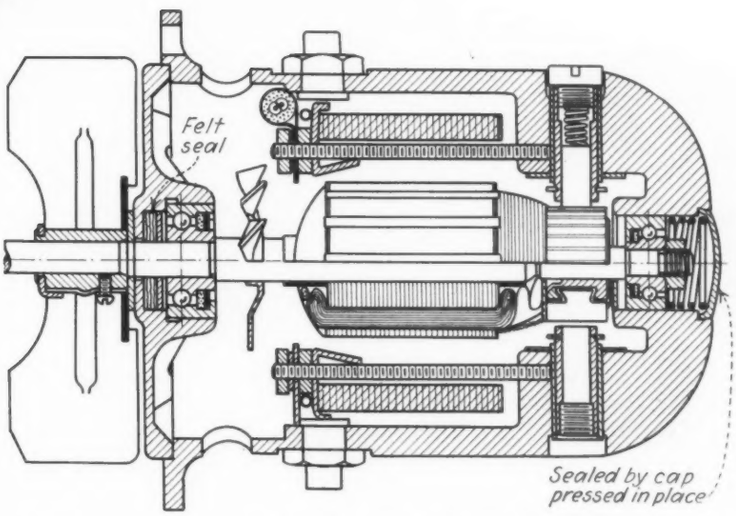


Fig. 4—Integrally felt-sealed ball bearings are used in the Eureka vacuum cleaner so that further lubrication is not required

At the other extreme, some types of bearings must be lubricated for the life of the machine, being especially true of household appliances. P. A. Shaad, chief engineer of the Eureka Vacuum Cleaner Company, says: "Our methods of lubricating various types of vacuum cleaners of present design are simple. It has been our aim to simplify these means as much as possible so that very little care and attention would be required of the housewife.

"Our present method consists of pre-lubricated completely sealed ball bearings in all motors. With reference to the seals for the motor bearings (as shown in Fig. 4) the commutator end bearings are completely inclosed on one end, and the other end, extended inward, has a seal built into the bearing. The fan end bearing is sealed on the fan side by a felt washer, which is held in place by a split steel washer. The other end is protected by an in-built seal."

In the revolving brush model of the Eureka cleaner, the brush bearings, Fig. 5, are of oil impregnated wood. They require no oiling and withstand the large amount of dust which passes around them. This type of bearing is built into a labyrinth seal in conjunction with a felt sealing washer and fiber thrust washer.

U. A. Whitaker, director of development and design of The Hoover Company, which manufactures electric vacuum cleaners, says in part: "The bearings of our motors are of the precision ball bearing type and all applications are protected from dirt and grease, the grease being held in by means of felt seals. In each

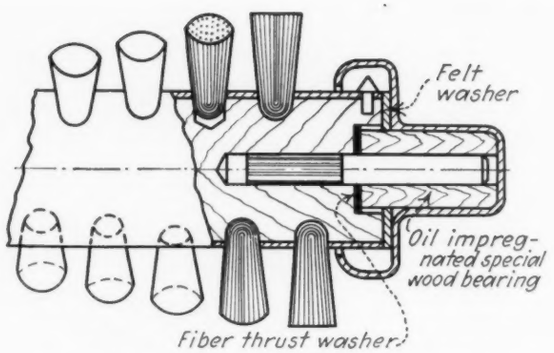


Fig. 5—Labyrinth seals incorporating felt and fiber washers are used to prevent dirt reaching the oil-impregnated wood bearings in the revolving brush of the Eureka cleaner

system, the bearings are packed with grease at the factory of the bearing manufacturer and are kept sealed in the paper wrapper until they are ready to be installed in the motor."

In Fig. 6, at *A*, is shown a magneto type ball bearing used at the upper end of a Hoover vertical motor. The top side of the bearing is permanently sealed with a cupped flange which is held in place with a snap ring. The lower side is sealed with a felt washer. Two felt seals protect the bearing at the lower end of the vertical motor shaft, illustrated at *B*. A non-separable ball bearing at *C* has an integral seal at the lower side, the upper end being permanently sealed with a plug washer.

Graphited bronze bearings are used in locations where lubrication is likely to be neglected or where it is impossible to supply oil. This type of bearing usually has small grooves cut into its bore, into which graphite is pressed. The graphite surface is approximately 50 per cent of the bearing area. The peripheral speed of the shaft must be sufficiently great, usually more than 30 ft. per min., so as to maintain a lubricating film. As graphite is not soluble in oil, gasoline or water, these bearings can be used in locations where oil-lubricated bearings would wear to destruction. The life of a graphited bronze bearing may be prolonged by an occasional application of oil or grease.

When the bearings are located in inaccessible places or when a disproportionately extra cost is involved for individual lubrication, force-feed or automatic lubrication can be used. The chief engineer of one of the airplane engine companies states that their general practice is to supply lubricating oil under pressure, sometimes with the quantity controlled, to all working parts of the engine except the piston bearings. They are aware that many of their bearings could well be lubricated by splash or gravity supply, but because this method results in an occasional failure from causes unknown, it is believed to be the best practice to supply lubrication under pressure, thus answering the criticism before it arises.

In Fig. 7 is shown a patented oiling device as used on an "Underdriven Extractor" manufactured by The American Laundry Machinery Company. The bearing is lubricated through a tube in the pulley fillet. The oil falls into the reservoir of the bearing support, from which it is fed through a hole to the shaft and then by way of a groove in the bearing support opposite the oil hole, to the thrust bearing below. From here it is automatically pumped up through the center of the shaft to an outlet hole, thereby lubricating the entire bearing surface.

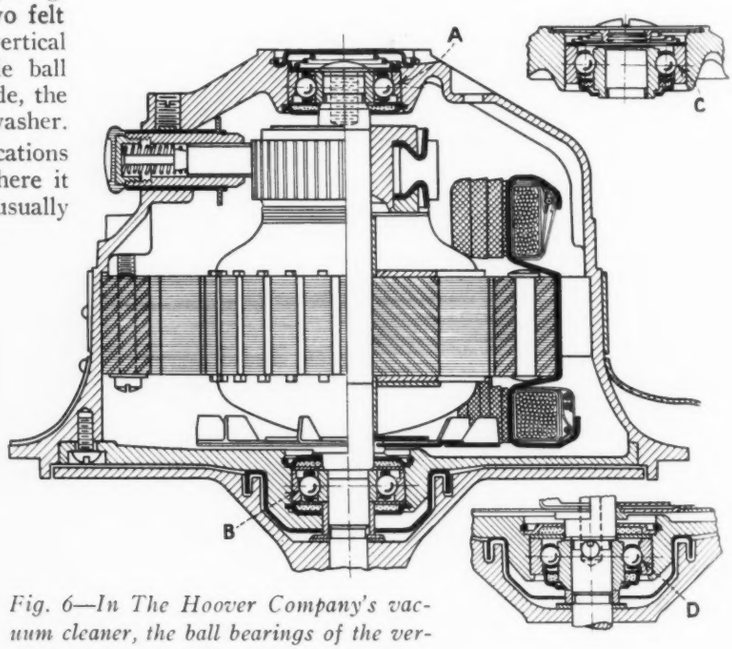


Fig. 6—In The Hoover Company's vacuum cleaner, the ball bearings of the vertical motor are felt sealed to retain the initial supply of lubricant

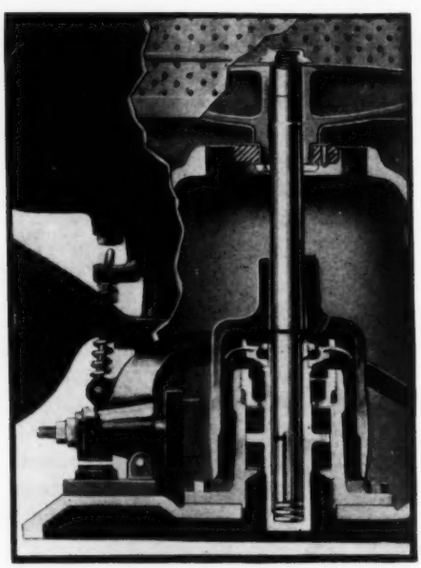
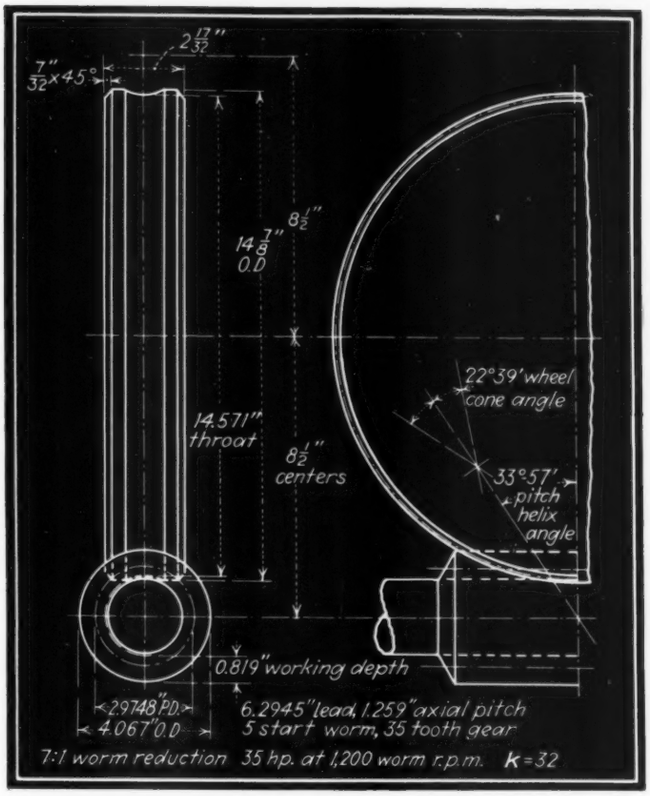


Fig. 7—The American Laundry Company's Underdriven Extractor uses an automatic pumping action to force the oil through a hole in shaft to center of drive-pulley, oversupply flowing back to reservoir



Principal dimensions are calculated from the center distance equation and the proportions given in Table II for this design

Standardized Worm Gear Sets

ROLAND V. HUTCHINSON

Design formulas that allow for effects of speed, ratio and center distance, giving well proportioned, economical gear sets

HIGH-GRADE bronze gear blanks being expensive, dimensional relationships yielding well-designed worm gearing at low manufacturing cost for moderate quantities must be based on blanks being sufficiently alike to make it possible to use the same patterns, chills, turning set-up and work holders.

In the design formulas developed to meet these conditions the two independent variables involved are center distance and velocity ratio, the gearing dimensions being expressed as functions of these variables. For well-proportioned worm gear sets the relationships in Table I apply to center distances from 4 to 18 in., for reduction ratios between 4 and 27 to 1, inclusive.

The precise shape of milled helicoidal threads produced by double-coned cutters or wheels varies with ratio of grinding wheel to work diameter and with lead. Geometrical similarity of large and small worms, ground by double-coned grinding wheels, is limited by the size of wheel that can be swung in the thread grinder.

Gear blank width may be reduced as centers increase. The relative curvatures of worm and gear teeth depend upon blank dimensions, gear centers, reduction ratio, lead of worm, its generatrix shape and position, and are independent of the number of starts in the worm. Except where accurate velocity ratios must be held, the number of starts selected may be varied with the center distance as shown in Table II.

To give a good compromise between shock resistance and best lubrication, the height of pitch plane is chosen approximately one-third up the working height of the worm tooth. For slight changes in ratio, particularly with low reductions, the number of gear teeth can be increased or decreased by one. This does not affect the worm and hob, but the load carrying capacity is modified slightly. For resisting starting shock, where beam strength of the gear teeth may be the controlling factor, worms with fewer starts are desirable. For drives subject to shock at speed, a greater number of starts is preferable.

For the series of dimensions in Table I, a capacity equation in terms of center distance C, worm-shaft speed S, and reduction ratio R enables direct evaluation of gear set dimensions to transmit H input. For chill-cast low-nickel bronze gears and carburized, hardened, ground and polished worms of 3115 steel:

$$H = \frac{KSC^{5/2}}{10^{(3/R)-0.1}SR + 1000R - 2000}$$

Values for S vary between 100 and 3,600 r.p.m. inclusive, and K is a service factor lying between 1.25 for industrial drives subjected to heavy shock loads and 12 for automotive passenger car axles. A value of 3.2 for K corresponds to a normal industrial installation transmitting steady loads without shock.

The equation may be rearranged and solved directly for center distances, or arranged to give a relation in terms of K to indicate duty imposed on the drive.

$$C = \left(\frac{H\,[10^{(3/R)-0.1}SR + 1000R - 2000]}{KS}\right)^{2/5}$$

$$K = \frac{H\,[10^{(3/R)-0.1}SR + 1000R - 2000]}{SC^{5/2}}$$

The following example illustrates the use of these relations. For a drive transmitting 35 input hp. at

Table I—Design Proportions for Standardized Worm Gear Sets

Gear blank outside diam.	$1\frac{3}{4}\,C$
Gear blank throat diam.	$1\frac{5}{7}\,C$
Gear pitch diam.	$\left(\frac{12}{7}-\frac{9}{4N}\right)C$
Gear blank face	$0.3\,C-0.0005\,C^2$
45 deg. corner chamfer	$0.025\,C$
Outside diam. of worm	$\left(\frac{2}{7}+\frac{27}{4N}\right)C$
Pitch diam. of worm	$\left(\frac{2}{7}+\frac{9}{4N}\right)C$
Lead of worm	$\frac{\pi n}{N}\left(\frac{12}{7}-\frac{9}{4N}\right)C$
Axial pitch of worm	$\frac{\pi}{N}\left(\frac{12}{7}-\frac{9}{4N}\right)C$
Pitch helix angle α	$\arctan\left(\frac{n}{N}\times\frac{48N-63}{8N+63}\right)$
Semi-included angle of grinding wheel	$\arctan\left(\frac{\cos\alpha}{2}\right)$
Working depth of tooth	$\frac{27C}{8N}$

C = center distance — N = teeth in gear
α = helix angle — n = starts in worm

1,260 r.p.m., with 7:1 reduction ratio and a K factor of 3.2, the center distance is:

$$C=\left(\frac{35\,[10^{(3/7)-0.1}\times 8400+5000]}{3.2\times 1200}\right)^{2/5}=8\tfrac{1}{2}\text{ in.}$$

Selecting from Table II the number of starts as 5, the principal dimensions of the gearing are:

Gear outside diameter . . . . . $1\frac{3}{4}\times 8\frac{1}{2}=14\frac{7}{8}$
Gear throat diameter . . . . . $1\frac{5}{7}\times 8\frac{1}{2}=14.571$
Gear face . . . . . $0.3\times 8\frac{1}{2}-0.0005\times(8\frac{1}{2})^2=2\frac{17}{32}$
45 deg. chamfer . . . . . $0.025\times 8\frac{1}{2}=7/32$

Outside diameter of worm, $\left(\frac{2}{7}+\frac{27}{4\times 35}\right)\times 8\frac{1}{2}=4.067$

Pitch diameter of worm, $\left(\frac{2}{7}+\frac{9}{4\times 35}\right)\times 8\frac{1}{2}=2.9748$

Lead of worm, $\frac{\pi\times 5}{35}\times\left(\frac{12}{7}-\frac{9}{4\times 35}\right)\times 8\frac{1}{2}=6.2945$

Axial pitch (adjusting lead to 6.295) = 1.259

Angle α, $\arctan\left(\frac{5}{35}\times\frac{48\times 35-63}{8\times 35+63}\right)=33$ deg. 57 min.

Cutter semi-angle . . . . . $\arctan\left(\frac{\cos\alpha}{2}\right)=22$ deg. 39 min

Tooth working depth . . . . . $\frac{27}{8}\times\frac{8\frac{1}{2}}{35}=0.819$

Lead may be modified to suit the change gears available. The cutter semi-angle gives an approximate axial pressure angle of 26 deg. 34 min., a reasonable compromise value.

The Barth factor customarily introduced into any equation for capacity of gearing, though superficially suppressed, is present in the equation given for H. Holding C and R constant and dividing by S, the equation reduces to a hyperbolic form similar to the Barth factor, the right-hand member taking the form:

$$\frac{p\,m}{m+x}$$

In the numerator of this relation the factor m, analogous to the constant a in the Barth factor equation, is multiplied by the constant p which depends upon the service conditions. The factor x corresponds to V, the velocity, in the Barth factor equation.

If intertooth contacts and contact between roller and plane are analogous, then allowable unit surface stress is independent of size, the lengths of contact lines and linear velocities of motion varying with center distance, and the allowable unit load varying with the square root of center distance. Hence, capacity will vary as the product of these three factors, that is, as the center distance to the 5/2 power.

Where input power is given, these equations are unique in leading directly to a design solution. Where output power is specified, equivalent input may be obtained by dividing by expected efficiency, using the following approximate formula in which n is the approximate efficiency, α is the helix angle given in Table I and u is the coefficient of friction.

$$n=\frac{\tan\alpha\,(1-u\tan\alpha)}{\tan\alpha+u}$$

Analysis of available data indicates that the relationships existing between u and pitch line velocity V up to 3,000 ft. per min., using good lubricants, is given by the empirical formula,

$$\log_{10}u=\log_{10}0.12-\tfrac{1}{4}\log_{10}V+0.278\sin(50\log_{10}V)$$

The parenthesis factor in the last term is read as a number of degrees of arc. A somewhat simpler but not as exact an approximation for V between 200 and 3,000 is,

$$u=0.5625\,V^{-0.433}$$

The two expressions for u agree within 5 per cent, which is sufficiently close for initial design.

Table II—Number of Starts in Worm

Reduction Ratio	Center Distance				
	4 in.	8 in.	12 in.	15 in.	18 in.
4–5	7–6	7–6	7–6	7–6	8–7
5–6	6–5	6–5	6–5	6–5	7–6
6–8	5–4	5–4	5–4	6–5	6–5
8–12	4–3	4–3	4–3	5–4	5–4
12–17	3–2	3–2	3–2	4–3	4–3
17–27	2–1	2–1	2	3–2	3–2

QUESTION AND COMMENT

Integral Lighting in Instruments

L. J. LUNAS
Verona, N. J.

● To control the operation of modern electrical power plants requires a large number of instruments and switches mounted on long switchboards. Because of the number of instruments that must be watched by the observer, the control panels are now made in a condensed size, with miniature instruments and control switches grouped in a semicircle about the operator's desk. In order to read these small instruments at a distance, the dials must be well lighted. Since the intensity of illumination supplied by external light cannot be controlled by the instrument designer, good readability can be assured only by built-in lighting.

Satisfactory lighting for instrument dials such as the one shown in Fig. 1 must meet the following requirements:

1. The entire dial surface must be uniformly lighted with no shadows, dark spots or glare.
2. Light intensity must be as high as possible, consistent with allowable temperature rise within the instrument case.
3. The lighting system must be as trouble-free as possible, but lighting units must be easily removable for replacing burned-out lamps.
4. Lamps must be of a standard type readily obtainable at reasonable cost.

In the design of the electrical indicating instrument shown in Fig. 1, the heat-dissipating characteristics of the case limited the capacity of the lamps to about four watts. Heat from lamps of higher wattage would increase the temperature within the case to the point where the accuracy and performance of the instrument might be affected.

In order to light the dial uniformly with a limited amount of light, two lamps were used, each rated at two watts. The two lamps were mounted in the lower corners of the case, the lamp filaments being shielded from direct view to prevent glare. The inside of the case and cover was finished in white to reflect and diffuse the light uniformly over the white dial. The

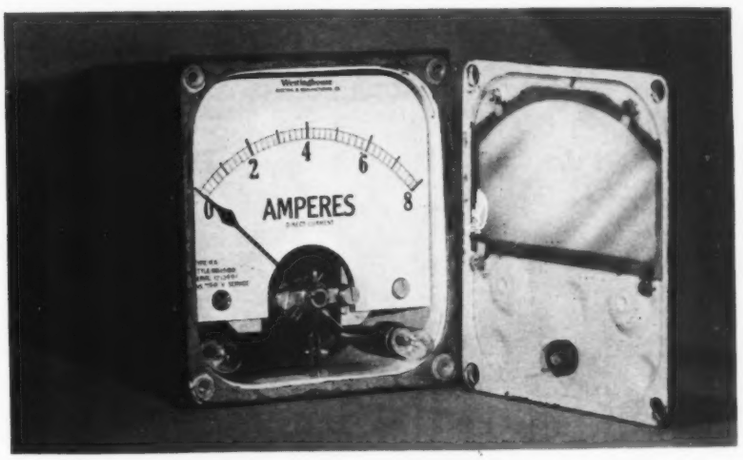


Fig. 1—White surfaces inside the instrument case reflect and diffuse the light from two small bulbs, uniformly lighting the dial

dial surface was only about $\frac{1}{16}$ in. from the inside of the glass window, and the lamp filament had to be placed within this space to spread the maximum amount of light over the dial.

To design the instrument mechanism and the lamp mounting as a unit separate from the case, the lamp mounting had to be comparatively long because of the depth required for the instrument mechanism. Also, it was desirable to have some pressure against the top of the lamp bulb to prevent the lamp from unscrewing and breaking contact. Therefore, the lighting unit was mounted in a bayonet socket, as shown in Fig. 2, with light spring pressure forcing the unit against the inside of the front cover. With this construction the light unit is easily removed for replacing a burned-out bulb.

The lamps are rated at 6.3 volts, and are of the type used in radio dials

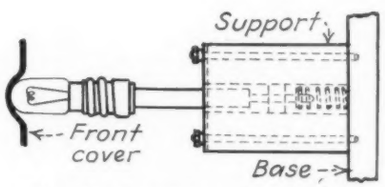


Fig. 2—Pressure of the bulb against the front cover prevents the lamp from rotating in the socket

so that replacements are readily obtained at low cost. By connecting the two lamps in parallel the failure of one lamp does not affect the other bulb, but the decreased intensity is a signal that a lamp needs replacing.

Worm Gear Contact

To the Editor:

● There is a strong tendency to confuse what might be termed "total contact" with instantaneous contact. If a worm and gear is mounted in place and the clean surface of the worm covered with Prussian blue, some of the pigment will be transfererd from the worm to the gear when the worm is rotated against a resisting torque applied to the gear. The field of contact will be defined by the blue on the gear teeth. The transferred pigment indicates that somewhere and sometime during the tooth engagement cycle, contact between worm and gear has occurred somewhere in the colored field. This indefinite statement gives no indication as to the sequence of events.

If instead of Prussian blue, the worm is given a light copper plate and the gear held against rotation, a torque shock applied to the worm will transfer some of the copper to the gear. The impact will leave a "foot

print" of the contact, showing the instantaneous contact conditions.

The first or "total contact" picture is the one usually used in inspection of gearing of known design characteristics. The second is used by comparatively few designers, but is valuable in confirming design calculations, clearly displaying the contact bands in well cut and well mounted gearing.

—ROLAND V. HUTCHINSON
Lansing, Mich.

Friction in Screw Threads

To the Editor:

● In the February number in "Intimate Correspondence" information was requested regarding the friction of steel threads in a bronze nut. Data on thread friction is included in *Bulletin No. 247,* "An Experimental Investigation of Screw Threads," by C. W. Ham and D. G. Ryan, published by the University of Illinois Engineering Experiment Station. The price of the bulletin is 35 cents.—C. W. HAM
University of Illinois

Graphical Averages

To the Editor:

● By the graphical method shown below, the numerical average for a series of numbers can be quickly determined by plotting each number to scale on vertical solid lines x, equally spaced. A line connecting the first two numbers, x_1 and x_2, cuts the mean on the dotted line m_2 that bisects the space; a line from m_2 to the third number x_3 cuts m_3 at the mean of the three numbers, and the procedure is continued for the remaining numbers. —O. E. BROWN
Case School of Applied Science

Drawing and Pattern Numbers

To the Editor:

● Many systems have been developed for making the drawing or pattern numbers convey other useful information, but few of these methods are flexible. For example, a truck manufacturer uses a symbol in which two letters designate the model, another one or two figures indicate the functional classification, and another digit is added for the size of the drawing.

Since most truck models do not remain current for more than two or three years, and most of the parts are carried over into new models, a bill of material for any current model will list a number of parts carrying some other model designation. The sheet size symbol in the drawing number does not permit a change in the drawing size when additional views are needed, or when the sheet size can be reduced. In addition, the symbols at times contain twelve or more figures and letters.

Only two items are necessary in a drawing symbol: the structural classification, and the material. The last digit in the symbol can be used to indicate the material classification, dividing all materials into four forms—castings, forgings, bar and sheet; and two kinds—ferrous and non-ferrous. Numerals from 1 to 8 represent these materials, 9 is for miscellaneous and zero is for assemblies. The final figure can be changed without altering the preceding figures.

The three digits preceding the material symbol are reserved for structural classifications. Preceding these three figures, is a serial number starting with 21, reserving numbers less than 21 for other purposes such as standard parts and plant layouts. Thus, the drawing number used for the first forged steel gear might be 217,652. If there were as many as 9,000 different spur gears made of forged steel, the drawing number would become 90,-217,652, but there are only eight digits in the complete symbol.

The structural classification number is a subject index requiring no cross references or tabulations, if the drafting room reference file follows the structural classification.

—HUBERT G. SMITH
Pontiac, Mich.

To the Editor:

● Engineers are apt to think in terms of mass production when generalizing about record systems and drawing numbers. For the manufacturer who builds special machinery, small changes in parts are often made on patterns that are in good condition, having been used for anly a few castings. But to fill replacement orders for parts that have been changed, it is desirable to make the change in the pattern so that it can be returned to its original condition if necessary.

New parts using a modified pattern are shown on a separate drawing with a new pattern designation bearing no relation to the original number. The basic, incomplete pattern carries both pattern numbers, while the loose pieces are given only the new pattern designation. Records of patterns and pattern changes are included in a loose-leaf binder with cross references to the pattern drawings.

—W. S. BROWN
Auburn, N. Y.

Special Centers With Standard Cutters

To the Editor:

● For the gear design specified by James A. Hall in the April number, page 149, a substitute pair of gears with a four to one ratio will be generated by a hob of the same pitch. The number of teeth in the pinion is:

$$\frac{36 + 159}{5} = 39 \text{ teeth}$$

The outside diameter of the 39-tooth pinion is:

$$\frac{39 + 2}{20} = 2.050 \text{ in.}$$

However, the maximum allowable diameter is 2.000 in., so that this pinion will have to be cut from a blank 0.050 in. undersize. If this blank is used with a 20 D. P. full-depth hob with a 20 deg. pressure angle, the teeth will be of correct involute curve form, but the pinion teeth will be thinner and the gear teeth thicker than standard.

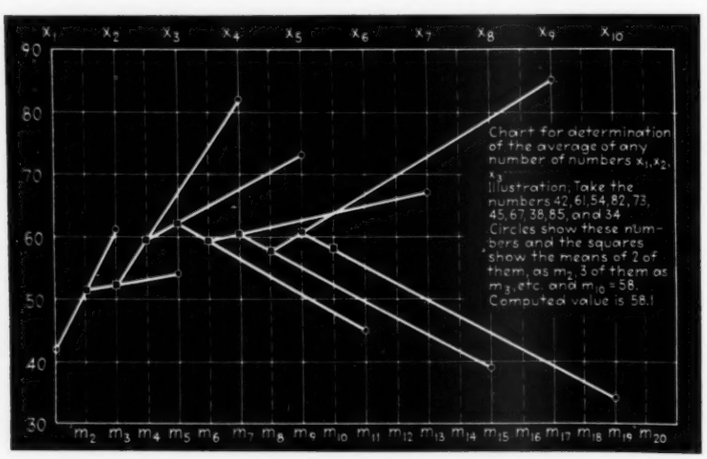
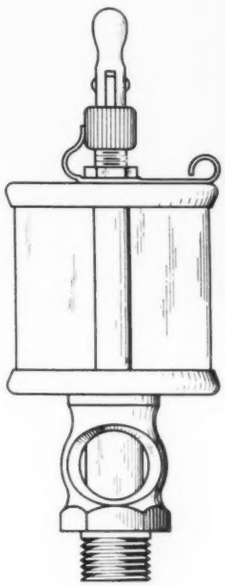
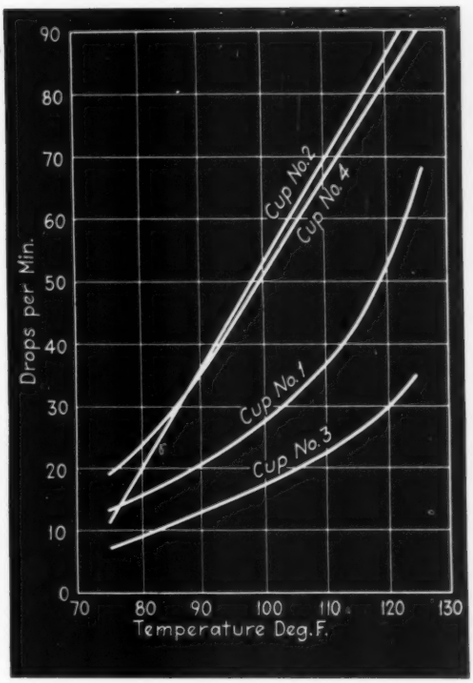
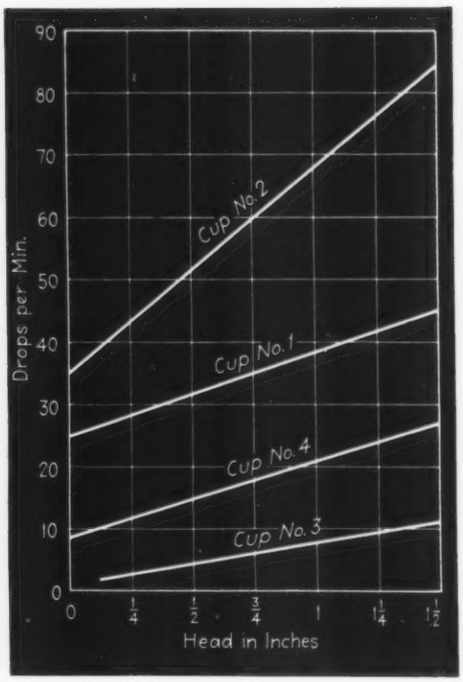

x1 x2 x3 x4 x5 x6 x7 x8 x9 x10
90
80
70
60
50
40
30
m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12 m13 m14 m15 m16 m17 m18 m19 m20
Chart for determination of the average of any number of numbers x1, x2, x3
Illustration: Take the numbers 42, 61, 54, 82, 73, 45, 67, 38, 85, and 34
Circles show these numbers and the squares show the means of 2 of them, as m2, 3 of them as m3, etc. and m10 = 58.
Computed value is 58.1

Fig. 1—(Below) Conventional type of oil cup in which the rate of feed depends on the oil temperature and the pressure head. Fig. 2—(Right) Effect of variations in head and temperature on the rate of feed for four types of oil cups







Thickness of the tooth on the pitch line is:

$$0.0785 - 0.05 \tan 20 = 0.0603 \text{ in.}$$

The base circle for the pinion is 1.832 in., while the root diameter is 1.784 in., resulting in a pinion undercut of 0.024 in. This pinion does not show any serious impairment, although it would be inclined to wear faster than a standard one, for the reason that the arc of approach would be increased by the reduction in diameter.

The mating gear of 156 teeth will be generated on an enlarged diameter of:

$$\frac{156 + 2}{20} + 0.050 = 7.950 \text{ in.}$$

This gear and pinion combination will run together on the same centers as the pair without backlash. A check on the number of teeth in contact gives a value of approximately 2, so that they will operate with adequate overlap.

—P. N. BLAND
Vancouver, B. C.

To the Editor:

● Since the total number of teeth in the gear and pinion is 195, the four to one ratio will require 39 teeth on the pinion and 156 teeth on the gear. The maximum outside diameter of 2 in. is the standard diameter for a pinion with 38 teeth, one tooth less than the required number. Therefore, the outside diameter of the gear should be made 7.95 in., which is the standard diameter for a gear with one tooth more than the required diameter.

Both pinion and gear may be cut with either a standard 20 deg. hob or Fellows cutter to the standard depth. The drive will operate at the new speed ratio on the same center distance used for the gear combination having 36 and 159 teeth.

—C. A. JOHNSON
Springfield, Mass.

Feeding Rate of Oil Cups

JAMES I. CLOWER
Assistant Professor of Machine Design
Virginia Polytechnic Institute

● For efficient use of lubricant combined with adequate oil supply, a good oiling device should be automatic, reliable, accessible for cleaning and repairs, low cost, designed to deliver a uniform feed under all operating conditions, and accurately adjustable to the desired feed rate.

Because of their wide use and suspected inefficiency, tests were run on four drop-feed oil cups of the type shown in Fig. 1. As shown by the curves in Fig. 2, changes in pressure head and temperature both affected the rate of flow, the flow decreasing with the pressure head and increasing with the temperature. The tests show that temperature changes have a more pronounced effect than changes in head. The effect was not the same for all four cups, because of the different flow characteristics of the orifices. Since this type of oil cup must be adjusted to deliver sufficient oil at the minimum temperature and head, under normal conditions the oiler delivers an excess of oil.

Many types of drop-feed cups on the market are designed to maintain a constant head, but none are designed to eliminate the effect of temperature changes on rate of feed. A cup designed to eliminate both head and temperature effects should find a ready market. Such a design would be more expensive as a thermostatically controlled valve would add some to the cost, but this feature would pay for itself in a short time by the oil saved.

Errata

● On page 67 of the February number, the explanation following Equation (3) in the article, "Distortion of Hollow Shafts and Pins," states that the bending moment is zero where $\sin \theta$ is $2/\pi$ or 93.5 deg. The correct value for the angle is 39.5 deg.

Also, in the Reference Book Sheet, page 159, in the April number, the first line in the last paragraph should read "area" instead of "circumference."

Thermostatic Mechanisms–I

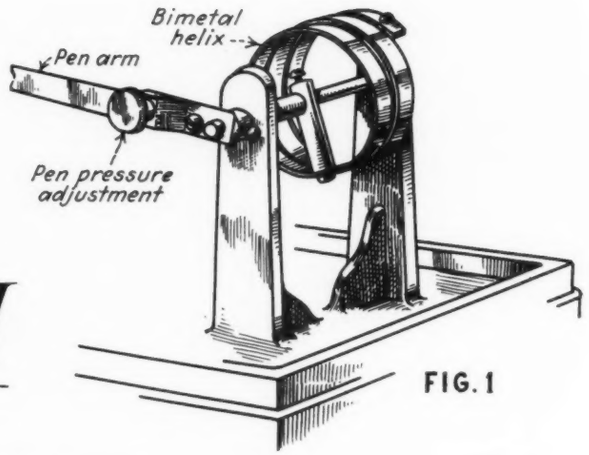


FIG. 1

IN THERMOSTATIC bimetals, the sensitivity or change in deflection for a given temperature change, depends upon the combination of metals selected to meet the operating temperature range as well as the dimensions of the bimetal element. Sensitivity increases with the square of the length and inversely with the thickness. The force developed for a given temperature change also depends on the type of bimetal, while the allowable working load for the thermostatic strip increases with the width and the square of the thickness. Thus, the design of bimetal elements depends upon the relative importance of sensitivity and working load.

Fig. 1—In the Taylor recording thermometer a pen is moved vertically across a revolving chart by a brass-invar bimetal element. To obtain sensitivity the long movement of the pen requires a long strip of bimetal, which is coiled into a helix to save space. For accuracy, a relatively large cross section gives stiffness, although the large thickness requires increased length to obtain the desired sensitivity.

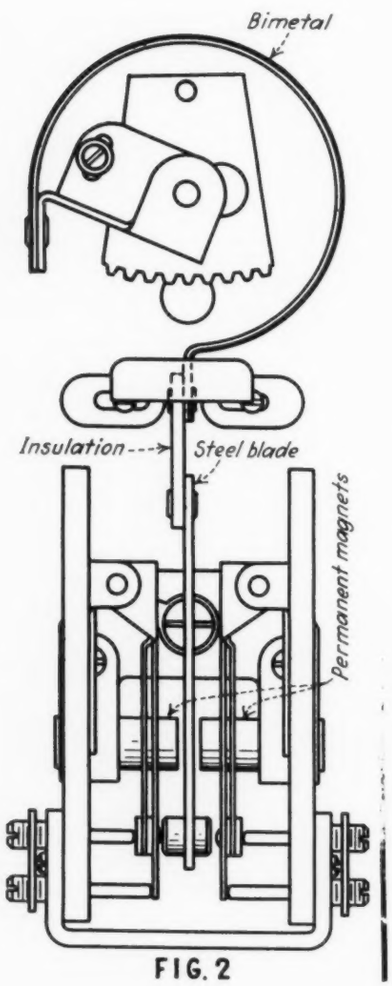


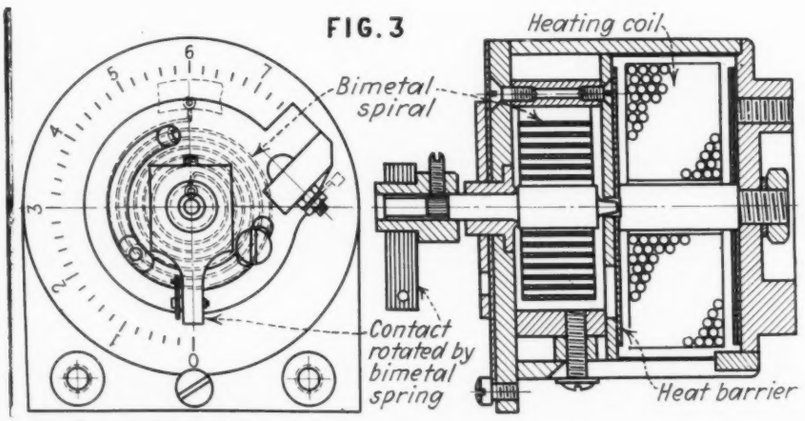
FIG. 2

Fig. 2—Room temperatures in summer as well as winter are controlled over a wide range by a single large-diameter coil of brass-invar in the Friez thermometer. To prevent chattering, a small permanent magnet is mounted on each side of the steel contact blade. The magnetic attraction on the blade, increasing inversely with the square of the distince from the magnet, gives a snap action to the contacts.

Fig. 3 — In this Westinghouse overload relay for large motors, a portion of the motor current is passed through a heating coil within the relay. Heat from the coil raises the temperature of a bimetal spiral which rotates a shaft carrying an electrical contact. To withstand the operating temperature, a heat resistant bimetal is used, coiled into the spiral form for compactness. Because of the large deflection needed the spiral is long and thin, while the width is made large to provide the required contact pressure.

By the use of heat barriers between the bimetal spiral and the heating coil, temperature rise of the bimetal can be made to follow closely the increase in temperature within the motor. Thus, momentary overloads do not cause sufficient

FIG. 3



heating to close the contacts, while a continued overload will in time cause the bimetal to rotate the contact arm around to the adjustable stationary contact, causing a relay to shut down the motor.

Fig. 4—On the Dodge carburetor, when the engine is cold a vane in the exhaust passage to the "hot spot" is held open by a bimetal spring against the force of a small counterweight. When the thermostatic spiral is heated by the outside air or by the warm air stream from the radiator, the spring coils up allowing the weight to close the vane. Since high accuracy is not needed, a thin, flexible cross section is used with a long length to give the desired sensitivity.

Fig. 5—In the Friez relay a constant current through an electrical heating coil around a straight bimetal strip gives a time delay action. Since the temperature range is relatively large, high sensitivity is not necessary, hence a short, straight strip of bimetal is suitable. Because of the relatively heavy thickness used the strip is sufficiently stiff to close the contact firmly without chattering.

Fig. 6—A similar type of bimetal element is used in the Ward Leonard time delay relay for mercury vapor rectifiers. This relay closes the potential circuit to the mercury tube only after the filament has had time to reach its normal operating temperature. To eliminate the effect of changes in room temperature on the length of the contact gap, and therefore the time interval, the stationary contact is carried by a second bimetal strip similar to the heated element. Barriers of laminated plastic on both sides of the active bimetal strip shield the compensating strip and prevent air currents from affecting the heating rate. The relatively high temperature range allows the use of a straight, thick strip, while the addition of the compensating strip makes accurate timing possible with a short travel.

Fig. 7—Oil pressure, engine temperature or gasoline level are indicated electrically on automobile dashboard instruments built by King-Seeley in which a bimetal element is used in both the sender and receiver. A grounded contact at the sender completes an electric circuit through heaters around two similar bimetal strips. Since the same current flows around the two bimetal elements, their deflections are the same. But the sender element when heated will bend away from the grounded contact until the circuit is broken. Upon cooling, the bimetal again makes contact and the cycle continues, allowing the bimetal to follow the movement of the grounded contact. For the oil pressure gage, the grounded contact is attached to a diaphragm; for the temperature indicator, the contact is carried by another thermostatic bimetal strip; in the gasoline level device, the contact is shifted by a cam on a shaft rotated by a float. Deflections of the receiving bimetal are amplified through a linkage that operates a pointer over the scale of the receiving instrument. Since only small deflections are needed, the bimetal element is in the form of a short, stiff strip.

Deflection equations for bimetals were given in "Mechanical Design of Thermostatic Bimetal Elements," by H. D. Matthews in November, 1933.

The second of this series of three articles on bimetal and bellows type thermostat applications will appear in the July number.

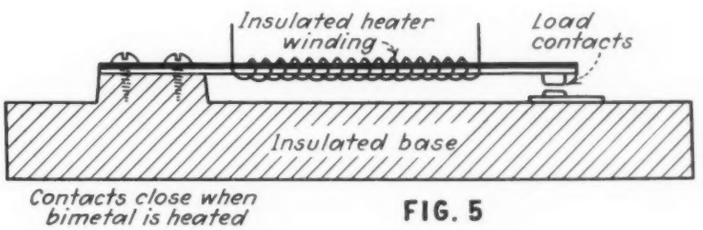


FIG. 5

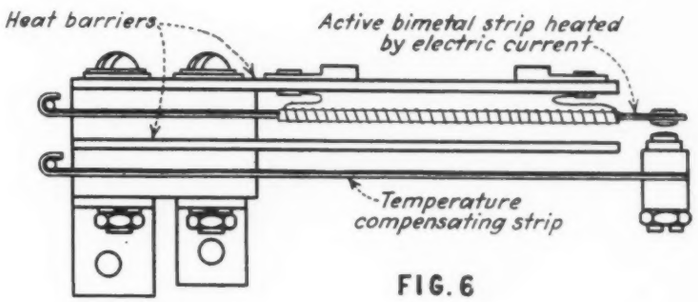


FIG. 6

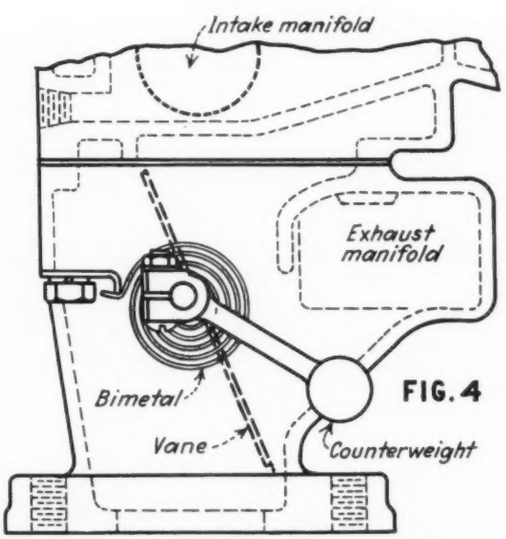


FIG. 4

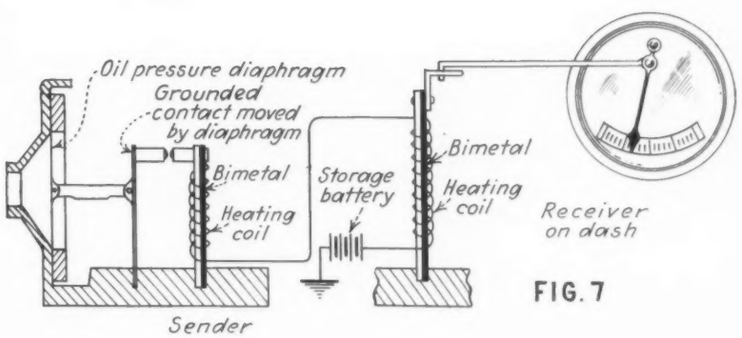


FIG. 7

NEWS

What happens when designers and client are one. The reception room in the new headquarters of Van Doren & Rideout in Toledo, Ohio. The chair frames are of aluminum strip with legs curved to give resiliency, radio cabinet is of their own design made in Plaskon, bookends are glass. Walls and ceiling are slightly off white, contrasting with mantle and dado sections which are deep blue, chairs are a fabricoid black except arm chairs which are red. White Venetian blinds add contrast.

Leipzig Trade Fair a Big Success

LEIPZIG Trade Fair just concluded its 1935 exposition with the largest and best attendance in several years, indicating a general revival in world trade. According to the official reports 180,000 buyers visited the fair this year, an increase of 40,000 over last year. More than 21,000 of the visitors were from foreign countries, an increase of 25 per cent over 1934. The United States sent 356 buyers representing a wide range of business interests. A total of 74 countries, located in every corner of the world, were represented at Leipzig this year.

The latest products of every conceivable industry were shown in the more than 8,000 exhibits, an increase of 12 per cent over last year. Early reports of business transacted at the fair were highly favorable and caused a rise in quotations on the Berlin exchange. In previous years the Leipzig Trade Fair has meant some $200,000,000 in export values for Germany. A large volume of business this year was satisfactorily arranged on a trade barter basis. The fair which has been held every year without interruption for 700 years has long been considered an accurate barometer of world trade and business conditions.

Sodium-Zinc Alloy Prevents Flaws in Non-ferrous Castings

FOR THE purpose of developing a deoxidizer that would eliminate the oxide and gas occlusions in brasses, the Grasselli Chemical Company and the "R & H" Chemical Division of the du Pont Company undertook a joint development and research investigation. As a result of this, they have now announced an alloy consisting of 98 per cent intermediate grade zinc and 2 per cent metallic sodium, which can be used in all non-ferrous alloys where a content of 2 per cent or more of metallic zinc can be tolerated or is required. Tests conducted by Scovill Manufacturing Company show that this deoxidizer not only reduces any metal oxides that are present in the bath, but also reduces segregations, gas occlusions and eliminates the necessity for mechanical puddling or stirring.

In using the sodium-zinc alloy, the brass batch is made up with less than the final desired amount of zinc in order to compensate for the additional zinc charge in the sodium-zinc alloy addition. When the batch is almost ready to pour fragments of the sodium-zinc alloy are added, the alloy breaking down into its components by reason of the high temperature encountered. The sodium, with a tremendous affinity for oxygen, energetically reduces any metallic oxides that are present in the batch, regardless of their state. The sole products of the reaction are sodium oxide and pure reduced copper, tin, zinc or the metal of whatever oxide was present in the batch before the addition of the deoxidizer.

Sodium oxide, which has a normal boiling point of 880 deg. C. while the temperature of the bath ranges from 900 deg. to nearly 1,100 deg. C., boils out of the bath with great vigor, resulting in a bubbling and stirring action. This is highly beneficial to the metal, reducing segregation and imparting a "liveness" which is quite noticeable even when the metal is being poured into the mold.

No harm is done to the physical properties of the brass, because of the use of the sodium-zinc alloy. In general, there results a slight increase in elastic limit, tensile strength, and elongation under fracturing loads. This effect of increase in strength is the result of the elimination of faults rather than to any significant change in the actual metallic structure.

Not only can sodium-zinc alloy be used with straight brasses, but it is also highly beneficial in the casting of copper-silicon alloys. These alloys are extremely difficult to cast satisfactorily because of the excessively frequent occurence of shrinkage holes. The effect of the sodium-zinc alloy is to decrease the viscosity of the metal when poured, as well as to eliminate refractory oxides, thus resulting in a much lowered occurrence of shrinkage troubles.

The New Products Division of the Grasselli Chemical Company has prepared bulletins giving detailed technical information and other data, which can be procured upon request. Samples of the material will also be submitted to those interested and in a position to use them.

Industrial Film On Design of Lathes

PICTURING in dramatic fashion the successive stages of the development of lathes, a new industrial film entitled "The Development of the Lathe" has recently been produced by the Monarch Machine Tool Company. Beginning with the original tree or pole lathe of 500 A.D., the film then shows the first wood screw cutting lathe of the fifteenth century, the first iron lathe of 1800 A.D., the first quick-change gear lathe of 1890 and the first geared head lathe of 1900.

Following the chronological development of the lathe, the film shows a number of the latest Monarch machines in operation, these including the Monarch Keller form-turning machine equipped with centrode device and oval chuck; the new Magna-Matic all electric, full automatic double carriage lathe, and the Monarch hand-feed surface grinder, together with specially tooled Monarch engine lathes.

It has been announced by Mr. W. E. Whipp of the Monarch Machine Tool Company that a limited number of these films are available in two sizes—about a thousand feet of 16 mm. safety-type film, and also about two thousand feet of 35 mm. film. Copies of these films are available for loan to industrial organizations, technical societies, educational institutions and others.

New A.S.T.M. Specifications

THE work which has been going on for the past three years under the direction of the American Society for Testing Materials, the American Electro-Platers' Society and the National Bureau of Standards has reached the state where specifications on the plated coatings on iron and steel are about ready for approval.

It is expected that three specifications will be issued shortly. These cover the following: Electro-deposited coatings of nickel and chromium on steel, electro-deposits of zinc on steel, electro-deposits of cadmium on steel. In each of the specifications two types of coating are covered, namely, coating for general service and coating for mild service. The requirements involve manufacture, thickness of deposits and, in the case of nickel and chromium coatings on steel, a continuity test is specified. Methods for thickness measurement are of course given in each of the three specifications.

Preparatory to developing the specifications, about 7,000 panels were exposed, plated in almost every way known to the plating industry and some very important facts were discovered. It was found that the plating usually used was considerably less in thickness than should be required in accordance with the findings of the test.

Appendices to the items give important supplementary information on time required for plating and explanation of symbols used as designations of the grades of plating.

At a recent meeting of the A.S.T.M. committee on iron-chromium, iron-chromium-nickel and related alloys considerable progress was reported on the formulation of purchase specifications for the chromium- and nickel-bearing steels. The committee expects to be able to present to the society in June five new specifications which will cover the annealed corrosion-resistant sheet steels, both plain chromium and chromium-nickel steels and also cold-rolled chromium-nickel steel. Drafts of the specifications were considered in detail by the subcommittee on specifications for flat products, and a number of improvements and changes were agreed upon before they were presented to the main committee. These specifications will be the first for these materials prepared by the committee and represent a significant trend in its work.

The subcommittee on specifications for castings also completed three new specifications for plain chromium-steel castings which were presented to Committee A-10 for presentation to the society for publication as tentative.

Crane Built in Record Time

ALTHOUGH no official records are available, it is believed that the record for the shortest time in which a crane of its size and capacity has ever been completed, is held by one recently built for the Inland Steel Company. The crane was finished in sixteen working days.

This 3-motor crane of 15-ton capacity, built in the Harnischfeger Shops at Milwaukee, has a span of 100 ft., and is entirely of steel construction with cast steel trolley frames. It is provided with mill type motors with full magnetic relay controls, composite type end trucks and platforms both sides of the bridge. Its total weight is 168,000 pounds. It was ordered for urgent delivery to handle production on a large tonnage contract involving continuous strip mill operations.

MEETINGS

American Gear Manufacturers Association—Annual meeting Penn-Lincoln Hotel, Wilkinsburg, Pa., May 14-15. J. C. McQuiston, secretary, Penn-Lincoln Hotel, Wilkinsburg, Pa.

American Iron and Steel Institute—Annual meeting, Hotel Commodore, New York, N. Y., May 23. W. S. Power, executive secretary, 350 Fifth Ave., New York, N. Y.

Society of Automotive Engineers—Summer meeting, The Greenbrier, White Sulphur Springs, Va., June 16-20. John A. C. Warner, secretary, 29 West 39th St., New York, N. Y.

American Society of Mechanical Engineers—Semi-annual meeting, Hotel Gibson, Cincinnati, Ohio, June 19-21. C. E. Davies, secretary, 29 West 39th St., New York, N. Y.

American Institute of Electrical Engineers—Summer meeting, Cornell University, Ithaca, N. Y., June 24-28. H. H. Henline, secretary, 33 West 39th St., New York, N. Y.

American Society for Testing Materials—Annual meeting, Book-Cadillac Hotel, Detroit, Mich., June 24-28. R. E. Hess, assistant secretary, 260 South Broad St., Philadelphia, Pa.

EXHIBITIONS

Industrial Arts Exposition—Rockefeller Forum, 30 Rockefeller Plaza, New York, N. Y., April 15-May 15. T. J. Maloney, manager, 386 Fourth Ave., New York, N. Y.

National Association of Purchasing Agents—Exhibit of materials and equipment, Waldorf-Astoria Hotel, New York, N. Y. G. A. Renard, secretary, 11 Park Place, New York, N. Y.

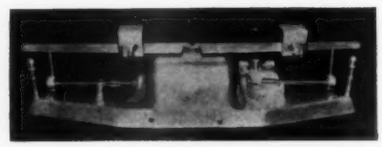
New Materials and Parts

Rotary Oil Burner Motor

To prevent oil vaporization and bearing carbonization which results from high heat in oil burner motors, a motor was developed in which the oil reservoir is at the lower end of the motor. In place of two bearings as in a standard motor, one long bearing is used which is part of the lower frame of the motor. The oil is pumped through the bearing by a groove in the shaft to the upper end of the bearing, from where it returns to the reservoir. It is claimed that the oil has a chance to cool and that any sediment settles. Oil is fed and strained through wicking to the bearings. Ohio Electric Mfg. Co., 5906 Maurice Ave., Cleveland, Ohio.

High-Speed Repeated Stress Machine

Two independent specimens, stressed as rotating cantilever beams are driven by a directly-connected motor at 10,000 r.p.m. A specimen is held in a chuck on either end of the shaft of the inclosed motor. The other end of the specimen is held in a chuck on one end of a bending arm. The free end of this arm rotates in a shielded ball bearing, carrying the weight of one end of the

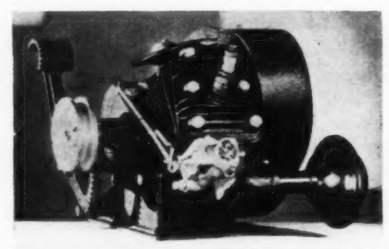


scale beam directly above. The scale beam, carrying a loading movable weight, is graduated in in.-lb. of bending moment. The only measurement necessary is that of the diameter of the reduced section of the specimen. The stress of the specimen is computed by the simple flexure formula. The motor, which is dynamically balanced, is designed for continuous high-speed service, and operates on 110 volts, a.c. or d.c. The machine is 28 in. long, weighs less than 30 lb. and does not require a special stand or fastenings. G. N. Krouse, 1737 Freeport Road, New Kensington, Pa.

Dust-Proof Solenoid Switch

Type E is inclosed in a black enameled sheet metal case, and dust-tightness is obtained with a thick felt gasket between cover and base. Type D is inclosed in a black enameled cast iron case, the surface between cover and base being machined to make a seal without the use of the gasket. This switch is used in hazardous locations, such as flour mills and pulverized fuel plants. The double break silver alloy contacts require no maintenance and eliminate flexible connectors. Soldered-type thermal overload relays which can be set without opening cabinet provide protection against overload. Available for polyphase motors up to 15 hp., 110 volts; 30 hp., 220 volts, and 50 hp., 440-550 volts, and for self-starting, single-phase motors. Allen-Bradley Co., 1311 S. First St., Milwaukee, Wis.

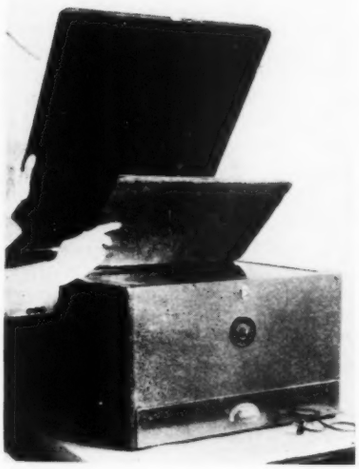
Four-Cycle Gasoline Engine



Has a single air-cooled cylinder of $\frac{5}{8}$ hp., and weighs 32 lb. Has a mechanical governor for smooth running, a counterbalanced crankshaft and aluminum alloy piston, and connecting rod with automatic oil distribution to all wearing parts, and a suction feed carburetor. The crankcase is vacuum sealed, and the cylinder is cooled by air from a built-in flywheel type of radial fan. The crankshaft is made of chrome-nickel-molybdenum electric furnace iron, counterweighted for balance and has steel-backed babbitt lined bearings. Johnson Motor Co., Waukegan, Ill.

Blueprinting Machine

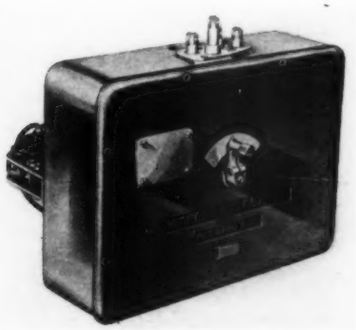
Model 100 is portable table type, using an Angstrom lamp of incandescent type which requires exposure of approximately one minute, and operates from regular 110-115 d.c. or a.c. lighting circuit without need of transformer choke coils. To make a print the tracing and paper are placed on a glass plate and clamped under the cover. An automatic timing switch is provided which clicks off when the print has had sufficient exposure. Print is then washed in water and



potash solution in trays provided for this purpose, and is dried on a special drying board furnished with machine. Prints up to 18x24 in. can be made. Milligan & Wright Co., 4614 Prospect Ave., Cleveland, Ohio.

Electric-Hydraulic Control

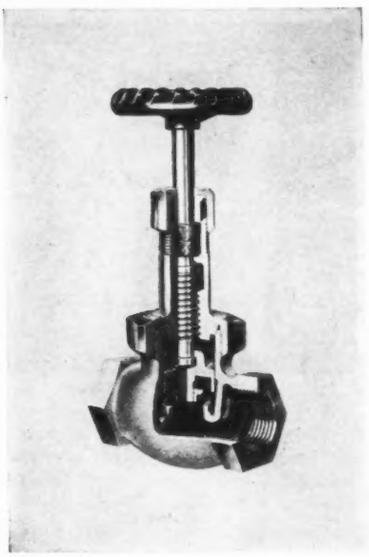
For machine tools and other equipment which require automatic feeds and rapid traverses. Starting, reversing and stopping are controlled electrically by pushbuttons or limit switches, relays and solenoids, built into control panels. A synchronous time relay which is varied by turning a dial, provides delayed reverse. Feed rates and rapid traverses are controlled hydraulically, being increased or decreased by stops (on work table) that depress either of the two center



plungers. A lever is provided for manual control for set-up purposes. Changes in work resistance or operating pressure of hydraulic system are said not to affect feed rates. Panel provides complete hydraulic circuit with exception of pump and cylinder. Available in several types and sizes. Vickers, Inc., Detroit, Mich.

Globe and Angle Valve

Has a spherical seat union joint between body and bonnet which prevents scraping when valve is being closed. By unscrewing the union nut the bonnet and valve stem assembly can be removed. The valve disk ring is made of asbestos compounded with a vulcanizing element. The valve stem has an Acme thread. The Fairbanks Co., 393 Lafayette St., New York, N. Y.

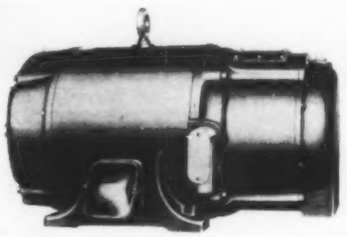


Isometric Lined Paper

Three dimensions sketches can be drawn freehand to any scale. Height is measured along vertical axes, length and width along the isometric horizontal lines. A double line "Y" in the center of the sheet shows the isometric principle at a glance. The axes are spaced 1 in. apart with subdivisions of $\frac{1}{4}$ in. making dimensioning unnecessary except for close limits. Available in pads 8x13 in., and in pocket size 4x6$\frac{1}{2}$ in. for field use, printed half scale. The Wade Instrument Co., 2274 Brooklyn Station, Cleveland, O.

Splash-Proof Motor

Is of slip-ring polyphase type and is constructed with baffled openings in the lower part of the end bracket to admit cooling air and exclude splashing water. The bearing bracket on the drive end is of one-piece construction and the bracket on the other end is constructed with a gasketed covered hand hole for a convenient inspection of brushes and rings. A pipe plug is used for access to the grease plug, and a removable section, covering the whole end of the bracket which protects the end assembly of the motor is provided. The frame and the end brackets are refined gray cast iron. Century Electric Co., 1806 Pine St., St. Louis, Mo.



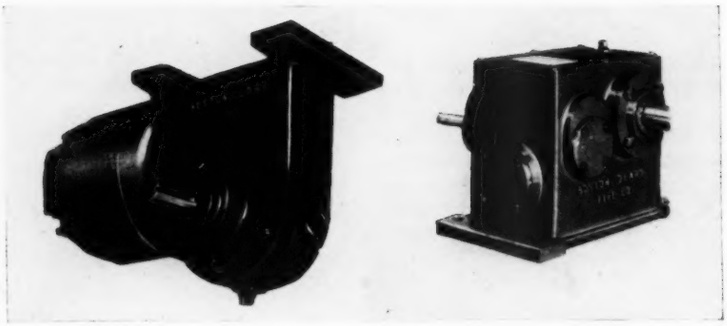
Radio Dials

Are finished in nickel-silver, with photo-etched engraving and are insulated from the shaft. The fluted knob is of polished black bakelite with rounded edges. Dials are $3\frac{1}{4}$ in. diam. and are available for $\frac{1}{4}$ and $\frac{3}{8}$ in. shafts with or without friction drive. General Radio Co., 30 State St., Cambridge A, Mass.

Speed Reducers—Inverted and Parallel Shaft

Type IMA at the left has a single reduction right-angle worm drive. Worm is hardened and ground steel and worm wheel is of phosphor bronze. Mounted on anti-friction bearings and has oil seals to prevent leakage. This type has torque capacities up to 263 lb.-in., and is said to run continuously at its rated capacity. Available in ratios of $3\frac{3}{4}$ to 1, up to 48 to 1, with $\frac{1}{6}$, $\frac{1}{4}$ or $\frac{1}{3}$ hp. a.c. or d.c. motors. Can be furnished without motor.

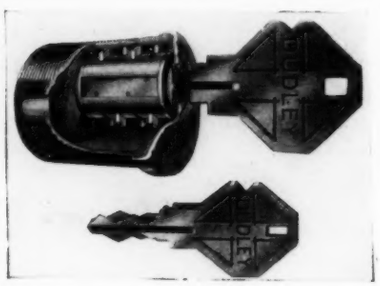
Type LD at the right has a double reduction worm and worm gear drive. Worms are made of hardened steel and threads are ground, while



the worm wheels are made of phosphor bronze. Shafts are mounted on tapered roller bearings. Available in 20 various ratios ranging from 37½ to 1, up to 1740 to 1. A bed plate can be furnished for motor if required. Boston Gear Works, Inc., North Quincy, Mass.

Pick-Proof Lock

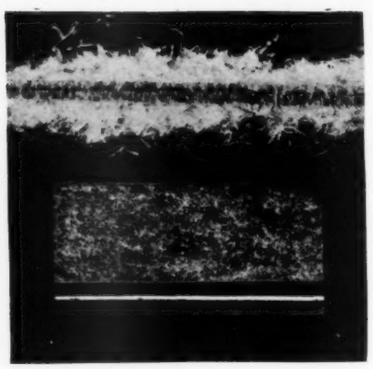
A cylinder lock, operated by a 4-edge key has four sets of flat pin tumblers. The hardened steel tumblers fit into slots in the cylinder and project above and below on both sides of the key center line. An armor steel plate over the lock case is grip proof which prevents the cylinder being twisted or wrenched loose. Keys are said to be



copy-proof and to have over ten million key changes. Fits any standard type of cylinder lock. Dudley Lock Corp., 235 W. Randolph St., Chicago, Ill.

Felt Bonded Metal

A metal coating is fused between the layer of felt and the base metal so that the fibers of the felt are embedded in the metal coating. This makes a bond which, it is said, will not separate because of heat, cold, moisture, fumes, mechanical friction, strain or distortion. Felt can be applied to one or both sides of the metal after which the metal can be bent or shaped without breaking the bond



with the felt. This material can be used in automobile bodies, airplane fuselages, metal shanks for shoes, telephone bases, office appliances and precision instruments. Can be finished with bakelite, lacquer, or plywood. The Felters Co., Inc., Boston, Mass., or H. H. Robertson Co., Pittsburgh, Pa.

Waterproof Silk

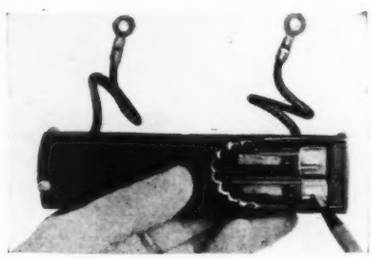
Although this light-weight and translucent material does not contain rubber, it is said to be waterproof, acid proof and heat proof, and that it will not stick, crack, harden or deteriorate with age and will take waterproof ink. It can be used industrially as a protection from gases, in thermostats, sealing the lining of electric refrigerators, labeling underground pipes and wires, in dry batteries, and as a substitute for tracing cloth. Available in three weights and in numerous colors. This fabric is processed by Westinghouse Electric & Mfg. Co. and distributed by Harte and Wyle, 267 Fifth Ave., New York, N. Y.

Luminescent Paint

Known as "Dialux" of which the principal element is sulphur of calcium, a phosphorescent salt. It is claimed that this paint does not contain any radio-active matter, and is not inflammable nor toxic. It can be applied to metal, glass, cloth, paper, wood or hard rubber compositions. Is made in two varieties, for brush application having a resin carrier, and for air gun spray application having an enamel carrier. Both varieties are said to dry quickly and to be of high mechanical resistance. It is used for indicating the position of objects in complete darkness. It may be used on dangerous parts of machinery, fire extinguishers, hydrants, projecting beams, staircases and dark corners, on electrical switches and live wires. Grobet File Corporation of America, 3 Park Place, New York, N. Y.

Magnet and Coil Protectors

An electronic device which is said to prevent insulation breakdowns in direct current magnets, solenoids, coils, shunt and compound wound motors and generators. The device is connected directly across the equipment to be protected. Its characteristics are claimed to be such that no current flows through the device



until the voltage reaches a dangerous value, when it shunts out the surge. Littelfuse Laboratories, 1772 Wilson Ave., Chicago, Ill.

Motor-Driven Gear Reducer

Helical gear reduction unit, known as Lectricgear, is driven by standard flange-mounted motor without any changes in the motor shaft or bearings. The gear reducer is built into an open frame base to which the foot-

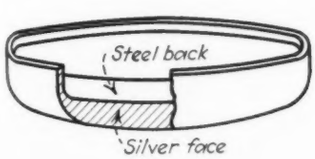
less motor is attached. Available in capacities of ⅛ to 2 hp., with or without motor. Several makes of motors can be used interchangeably. The Ajax Flexible Coupling Co., Westfield, N. Y.

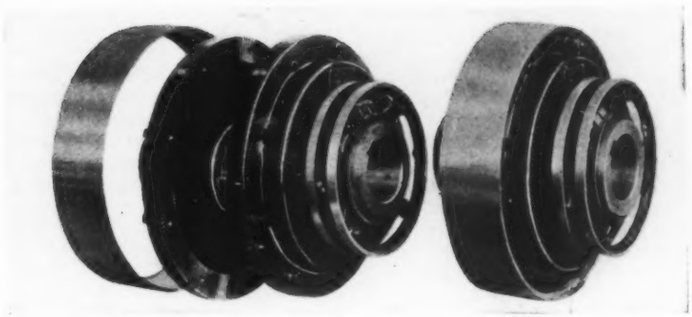
Recessed and Self-centering Screws

The principle of the "Phillips" screw is that the tapered recess in the head fits the tapered end of the driver by which the center of the screw is automatically found. It is stated that this type of screw has three times as much gripping area for the screwdriver, as has a slotted screw, making possible greater strength and increased torsion. As the driving slots do not extend to the periphery of the head, it is claimed that the wood or metal is not marred, and that very little down pressure is required to hold the driver in the screw. These screws can be placed on the end of the driver and moved into position with one hand. Only two sizes of drivers are required for a screw range of Nos. 5 to 16, inclusive. Bits for numerous power-driven screwdrivers are available. American Screw Co., Providence, R. I.

Laminated Contact Button

For electrical contact, is made of silver backed with steel. It is said that the laminated buttons cost less and wear longer than solid silver. Available with suitable production areas on the back which facilitates spot welding to support members of steel, brass or copper, and are made with flat or dome contact bases in various sizes. It is claimed that this type of button does not lose its shape when contact vibrates and pounds together. General Plate Co., 30 Forest St., Attleboro, Mass.





Magnetic Clutch for Positive Engagement

Has teeth cut into the outer faces of the driving disks which are said to develop high torques within limited diameters, making it suitable for heavy loads and high speeds. Engagement and disengagement is made at low speeds or at a stand-still to prevent injury to the teeth. Clutch release is obtained through spring pressure. An outer shell, as shown, is provided for dusty locations to shield the teeth from grit, dirt and magnetic dust. The clutch is available in a number of sizes, the one illustrated being 20 in. diam. Magnetic Mfg. Co., Milwaukee, Wisconsin.

MANUFACTURERS' PUBLICATIONS

Ampco Metal—Ampco Metal, Inc., Milwaukee, Wis. Engineering Data Sheet No. 14, 8½x11 in., of a series of data sheets of non-ferrous metals, describes Grade 22, an Ampco alloy, having a tensile strength of 100,000 lb. per sq.in. with a Brinell hardness of 321-341 and which is 19 per cent less in weight than SAE bronze.

Automatic Electric Motor Control—Monitor Controller Co., 51 South Gay St., Baltimore, Md., catalog 8½x11 in., 138 pages. Giving characteristic features and general description of d.c. reversing and non-reversing magnetic controllers, magnetic contactors, current limit starters, time element starters and controllers, and rheostats. Also various types of a.c. magnetic contactors, across-the-line, automatic and reversing starters, numerous switches and pushbutton stations.

Ball and Roller Bearing Housing Closures—The Bearing Appliance Co., Ardmore, Pa. Seven data sheets 8½x11 in., showing detailed dimensions of finished, ready-to-use applications for anti-friction bearings. Cast-iron closures include closed covers, open covers with slingers, having felt or leather oil seals. The covers are available in 14 sizes and approximately 150 sizes of ball and roller bearings can be fitted for various design combinations.

Chains—C. O. Bartlett & Snow Co., 6200 Harvard Ave., Cleveland, Ohio. Bulletin No. 74, 6x9 in. Standard types of detachable, pintle, Ley bushed, combination, drag, roller, transfer, steel bushed and drop forged chains and chain attachment are illustrated, and dimensions, weight and working loads are given for each size. Information is given on sprocket wheels, collars, take-ups, elevator buckets, shafting, spur and miter gears and girt and bevel gears.

Condensers—Aerovox Corp., 70-82 Washington St., Brooklyn, N. Y. Catalog No. 152, 24 pages, 8½x11 in. Describes condensers for industrial use and illustrates various types of condenser containers, showing construction and sizes by cross-section and outline drawings. Engineering data with power charts are included.

Enamel Finishes — Ferro Enamel Corp., Cleveland, Ohio. Booklet "Ferro Service," 16 pages, 8½x11 in., shows pictorially a number of tests for fusion resistance to impact and heat shock with views of various departments in the Ferro plant. Numerous testimonial letters and comments are included.

Gears & Sprockets — The Medart Co., Potomac and DeKalb Sts., St. Louis, Mo. Catalog, 8½x11 in. 80 pages, listing cast iron molded spur, bevel and miter gears and racks, cut tooth spur, bevel and miter gears made of rawhide, Textolite and Fabroil. Mortise spur, bevel and miter gears, and worm gears, various types of chains and sprockets, couplings and take-up bearings are also listed. Pages for horsepower calculations, keyseat charts and computing graphs for rawhide pinions are included.

Industrial Equipment—L. O. Koven & Brother Inc., 147 Ogden Ave., Jersey City, N. J. Catalog "Koven Industrial Equipment," 52 pages, 8½x11 in., describing and illustrating a varied line of fabricated equipment made of different types of material including stainless steel, "Steel Clad" metal and

plastic resins. Among these products are tanks for process and storage, equipment for chemical and allied industries, mixers for all purposes, various equipment for food industries, marine equipment, plate and sheet metal work, built-up welded construction, containers, cabinets, racks, sinks, stands and tables. It is announced that the galvanizing shop is equipped to handle work of unusual size and the engineering and consulting service has a file of more than 50,000 drawings.

Motors—The Louis Allis Co., Milwaukee, Wis. Bulletins 507-B, 510-B and 514-A, four pages each, 8½x11 in., explain the salient features of d.c. motors, totally inclosed fan-cooled motors and self-contained capacitor, single-phase motors with detailed cutaway photographs and brief notes.

Rheostats & Resistance Units — Ohmite Manufacturing Co., 636 N. Albany Ave., Chicago, Ill. Catalog No. 11, 8½x11 in., 8 pages, listing different sizes of rheostats, various types of resistors and resistor cords.

Rubber Goods—Mechanical — New York Belting & Packing Co., Passaic, N. J. Catalog 96 pages, 8½x11 in. Information about hose, belting, packing and other mechanical rubber products. Contains diagramatic drawings of various applications and tables of belt speeds, steam pressures, and temperature, carrying capacities, and numerous formulas and examples of their usage.

S.A.E. Steels Specification Charts—Republic Steel Corp., Massillon, Ohio. A recent revision of the list of standard S.A.E. steels, giving chemical compositions of carbon steels, free-cutting steels, corrosion and heat-resisting alloys, and manganese, chromium, nickel, nickel-chromium, molybdenum, chromium-vanadium, tungsten and silicon-manganese steels.

Spauldite—Spaulding Fibre Co., Inc., Tonawanda, N. Y. Folder, 4 pages, 8½x11 in., "Spauldite Sheets," describes electrical, mechanical and chemical properties and various grades for gears, valves and other products. Engineering data and various strengths are also included.

Steel—Lukens Steel Co., Coatesville, Pa. Booklet "World's Largest Plate Mills and Its Products," 8 pages 8½x11 in., gives a pictorial summary of the work done by this company and its divisions, By-Products Steel Corp. and Lunkenweld, Inc. Welded, cast, pressed and blank work is shown with captions explaining each picture.

Thermostatic Bimetal—General Plate Co., 30 Forest St., Attleboro, Mass. Handbook "Truflex Thermostatic Bimetal," 20 pages, 8½x11 in., gives facts of numerous types of bimetal now in use. Various applications to devices heated with gas, electricity, oil, hot water or steam. Contains charts for rapid calculating of proper bimetal elements to be used and information on laminated sheets, tubing and wire made of base metal covered with precious metal used for fabricating equipment that must resist corrosion.

"Thiokol B"—Thiokol Corp., Yardville, N. J. Additional compounding information in five typewritten pages to be added to Bullein B-1, giving tensile properties, resistance to solvents and flexibility at low temperatures.

Tubing Weight Tables — Timken Steel & Tube Co., Canton, Ohio. "Master Weight Tables," 9 pages, 8½x 11 in. Tables of weights of round hot finished and cold drawn steel tubing, $\frac{1}{16}$ in. to 10¾ in. O.D., and wall thickness of 36 B.W.G. to 1⅛ in. Printed in two colors on heavy paper for minimum and average wall thickness. Weights given to two and three decimals.

Valves—Parker Appliance Co., 10320 Berea Road, Cleveland, Ohio. Bulletin No. 38, 60 pages, 8½x11 in., lists globe, cross blow-down, by-pass, taper plugs, needle, check, release, disk and water service valves. Also illustrates strainers, pressure snubbers, air vents and cocks in various sizes and capacities. Illustrated with photographs and cross-section line drawings.

BOOKS AND BULLETINS

Principles of Mechanism

C. E. Pearce. 283 pages, 6x9 in. 312 illustrations. Red clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $3.50.

Since it is written as an introductory text for college students having little first hand knowledge of machinery, the book is restricted to elementary mechanisms and simple machines. Mechanisms for transmission of power are separately described and analyzed in chapters on friction drives, gears, worm drives, belts and chains. Types of intermittent motion produced by cams and linkages are presented.

Each chapter includes definitions and classifications of the types of mechanisms, subdivided in numbered sections. Fundamental relations are developed and an extensive list of problems is included at the end of each chapter.

Internal Combustion Engine

Vol. II—The Aero-Engine.

D. R. Pye. 398 pages, 6x9 in. 145 illustrations, 57 tables. Blue clothboard covers. Published by Oxford University Press, 114 Fifth Ave., New York, N. Y. Price $7.

Although written for designers of airplane engines, much of the material given in each chapter is reference material for the design of any type of internal combustion engine.

Included in Chapter II is a discussion of the factors in aircraft design that influence the power required, as well as engine speed and propeller performance. Limiting factors in engine performance are given in Chapter III with special attention to the practical limits of present designs.

Chapters on piston and valve temperatures, lubrication and lubricants and principles of heat transfer include fundamental data applying to the design of air-cooled or water-cooled engines for airplane or land use. Separate chapters discuss principles of heat flow from finned cylinders and radiators for liquid cooling.

Carburetors and superchargers are treated in separate chapters dealing with fundamental design formulas and principles. Closing chapters present an analysis of complete engine performance and fuel economy. An 8-page index is included.

Cross-section diagrams — but no photographs—in some of the chapters supplement the design material. Along with design principles and formulas, generous use is made of curves, charts and tables throughout the text, making the book an excellent reference source.

The Creep and Fracture of Lead and Lead Alloys

University of Illinois, Engineering Experiment Station, Urbana, Ill., in cooperation with The Utilities Research Commission. Bulletin No. 272 by Herbert F. Moore, Bernard B. Betty and Curtis W. Dollins, 50 pages.

Instead of estimating the resistance to creep from the rate of creep alone, the McVetty method of estimating the total creep in a given time under a given stress and at a given temperature has been developed for lead and lead alloys. A comparison of the average values of creep in one year for four metals (lead, antimony lead, tin-lead, and calcium-lead) is presented. Some creep tests on specimens containing oxide inclusions are reported. A number of tests to fracture the lead and lead alloys under steady load and under repeated cycles of reverse bending have been made. This bulletin is distributed free of charge until September 1, 1935.

Gear Design Calculations—III

CHARLES S. DeLATE

Spur Gears

Given the torque, tooth pressure angle, *D.P.*, gear ratio and limiting face width, the example shows the procedure of calculations when wear is the main factor of consideration.

Problem—Design a pair of hardened steel 20-deg. stub tooth gears of 8 *D.P.* having a ratio of 1.56 to 1, and a torque of 200 ft.-lb. at 3,200 r.p.m. The limiting compressive stress of Sf = 220,000 lb. per sq.in. The face width must not exceed 0.875 in. The measured tooth error is 0.001 in.

Computation of tooth load for wear:

$W_w = W_d \qquad W_d = T(W + I)$

$$W_w = \frac{2r}{r+1} Td \frac{Sf^2 \sin\phi}{1.4}\left(\frac{1}{E_1} + \frac{1}{E_2}\right)$$

W_w = Maximum static tooth load for wear
W_d = Total dynamic tooth load
W = Tangential load in lb. per in. of tooth width
W = Torque $\times$ 12/ (d/2 $\times$ T)
T = Tooth width = 0.875 in.
d = Pitch diameter of pinion
r = Gear ratio = 1.56 to 1

Assume 34 teeth and 53 teeth.

Sf = Limiting compressive stress = 220,000 lb. per sq. in.
ϕ = Pressure angle of tooth system

$$\frac{Sf^2 \sin\phi}{1.4}\left(\frac{1}{E_1} + \frac{1}{E_2}\right) = \text{Stress factor}$$

I = Increment load in lb. per in. of tooth width

$$I = \frac{0.05Vf}{0.05V + \sqrt{f}}$$

V = Pitch line velocity in ft. per min.
f = Load in lb. per in. of tooth width required to deflect the tooth a distance equal to the tooth error

$$f = \frac{eEZ_1Z_2}{Z_1 + Z_2} + W$$

e = Measured tooth error in in. = 0.001 in.
E = Modulus of elasticity = 30,000,000 lb. per sq.in.
Z_1 = Elastic form factor for pinion tooth
Z_2 = Elastic form factor for gear tooth
Z = Can be obtained from a form factor table in a gear book

Z_1 = 0.11168 $\qquad Z_2$ = 0.11306
Assume $Z_1 = Z_2$ $\qquad$ Average of Z_1 and Z_2 = 0.11237

Compute the pitch diameter for the pinion

$$V = \frac{\pi d}{12} \times 3{,}200 = 838d \text{ ft. per min.}$$

$$W = \frac{200 \times 12 \times 2}{d \times 0.875} = \frac{5{,}490}{d}$$

$$f = \frac{0.001 \times 30{,}000{,}000 \times 0.11237^2}{2 \times 0.11237} + \frac{5{,}490}{d}$$

$$f = 1{,}690 + 5{,}490/d$$

$$I = \frac{0.05 \times 838d\,(1{,}690 + 5{,}490/d)}{0.05 \times 838d + \sqrt{1{,}690 + 5{,}490/d}}$$

$$W_d = 0.875\left[\frac{5{,}490}{d} + \frac{41.9d \times 1{,}690\,(1 + 3.245/d)}{41.9d + 41.1\sqrt{1 + 3.245/d}}\right]$$

$W_w = 840d \qquad W_d = W_w$

$$\frac{5{,}490}{d} + \frac{70{,}900d\,(1 + 3.245/d)}{41.9d + 41.1\sqrt{1 + 3.245/d}} = 960d$$

By trial and error d = 3.88 in.

$n = d \times$ *diametral pitch* = Number of teeth in pinion
n = 3.88 $\times$ 8 = 31.04 use 32 teeth in pinion

$$d = \frac{32}{8} = 4.000 \text{ in.} \qquad r = 1.56 = \frac{N}{32}$$

N = 50 teeth in gear

Pitch diameter of gear = 50/8 = 6.250 in.
Face width = 0.875 in.

Check of computations using 32 and 50 teeth

Z for 32 teeth = 0.11145
Z for 50 teeth = 0.11291

$$W_d = T(W + I) = \frac{0.001 \times 30{,}000{,}000 \times 0.11145 \times 0.11291}{0.11145 + 0.11291} + \frac{5{,}490}{4} = 3{,}052 \text{ lb.}$$

$$I = \frac{0.05 \times 838 \times 4 \times 3{,}052}{0.05 \times 838 \times 4 + \sqrt{3{,}052}} = 2{,}295 \text{ lb.}$$

W_d = 0.875 (1,372 + 2,295) = 3,209 lb.
W_w = 840 $\times$ 4 = 3,360 lb.

$$\frac{3{,}360 - 3{,}209}{3{,}360} \times 100 = 4.46 \text{ per cent margin of safety}$$

Therefore, design is correct since W_w is greater than W_d

Helical Gear Design

Given the center distance, ratio, stress, torque, end thrust and tooth form of a pair of helical gears on parallel shafts, the pitch diameters, *N.D.P.*, helix angle, face width, tooth overlap and number of teeth in contact can be calculated.

Problem—Design a pair of helical gears to run on parallel shafts having a center distance of 2.750 in. and a ratio of 1.353 to 1. Design the pinion for a fiber stress of 40,000 lb. per sq.in., with 20 deg. stub tooth form, using the Lewis formula, the end thrust on the pinion not to exceed 1,000 lb. The pinion acts under a torque of 200 ft.-lb. Determine the number of teeth in contact.

N = Number of teeth in gear
n = Number of teeth in pinion
$N.D.P.$ = Normal diametral pitch
D = Pitch diameter of gear
d = Pitch diameter of pinion
C = Center distance = 2.750 in.
θ = Helix angle
θ_a = Approximate helix angle

$$G = \text{Gear ratio} = \frac{N}{n} = \frac{D}{d} = 1.353$$

To compute pitch diameters of gear and pinion:

$$\cos\theta = \frac{N + n}{2\ N.D.P. \times C} \qquad (1)$$

$N = N.D.P. \cos\theta D$
$n = N.D.P. \cos\theta d$

By substitution in Equation (1)

$$\cos\theta = \frac{N.D.P. \cos\theta D + N.D.P. \cos\theta d}{2\ N.D.P. \times C}$$

$2C = D + d = 2 \times 2.750$ in. $= 5.5$ in.
$D = 1.353d$ $\qquad 5.5 \text{ in.} = 1.353d + d = 2.353d$
$d = 2.3376$ in. $\qquad D = 5.5 - 2.3376 = 3.1624$ in.

$$\frac{N}{n} = 1.353$$

Use $N = 23$ teeth $\qquad n = 17$ teeth

Computing width of gear face:

$W = STpy$
W = Tangential load on pinion
S = Fiber stress on pinion = 40,000 lb. per sq.in.
T = Width of gear face
p = Circular pitch
y = Lewis form factor

$$W = \frac{\text{Torque in lb.-in.}}{\text{Pitch radius}} = \frac{200 \times 12}{2.3376/2} = 2{,}053 \text{ lb.}$$

End thrust on pinion $= W \tan\theta_a$

$$\tan\theta_a = \frac{1{,}000}{2{,}053} = 0.48709$$

$\theta_a = 25$ deg. 58 min.

Substituting for Equation (1)

$$\cos 25 \text{ deg. } 58 \text{ min.} = \frac{23 + 17}{2\ N.D.P. \times 2.750}$$

$$N.D.P. = \frac{40}{5.5 \times 0.89905} = 8.1 \qquad \text{Use } N.D.P. = 8$$

Checking for helix angle θ

$$\cos\theta = \frac{23 + 17}{2 \times 8 \times 2.750} = 0.90909 = 24 \text{ deg. } 37 \text{ min.}$$

Checking for end thrust:

$W \tan\theta = 2{,}053 \times \tan 24$ deg. 37 min. $= 942$ lb.

n^1 = Formative number of teeth in pinion

$$= \frac{n}{\cos^3\theta} = \frac{17}{\cos^3 24 \text{ deg. } 37 \text{ min.}} = 22.7 \text{ teeth}$$

$y = 0.12955$ for 22.7 teeth with 20 deg. stub tooth form

$$T = \frac{W}{Spy} = \frac{2{,}053}{40{,}000 \times \frac{\pi}{8} \times 0.12955}$$

$= 1.008$ in. wide

To find total number of teeth in contact:

$$\text{Number of teeth in contact} = \frac{N}{2\pi}\left[\tan\cos^{-1}\frac{B}{R + A} - \tan\phi\right] + \frac{n}{2\pi}\left[\tan\cos^{-1}\frac{b}{r + a} - \tan\phi\right]$$

B = Base circle radius of gear
b = Base circle radius of pinion
R = Pitch radius of gear = 1.5812 in.
r = Pitch radius of pinion = 1.1688 in.

$$A = a = \text{Addendum} = \frac{0.800}{N.D.P.} = 0.100 \text{ in.}$$

ϕ = Angle of tooth form = 20 deg. stub tooth
$B = R \cos\phi = 1.5812 \times 0.93969 = 1.488$ in.
$b = r \cos\phi = 1.1688 \times 0.93969 = 1.097$ in.

Number of teeth in contact:

$$= \frac{23}{2\pi}\left[\tan\cos^{-1}\frac{1.488}{1.5812 + 0.100} - \tan 20 \text{ deg.}\right] + \frac{17}{2\pi}\left[\tan\cos^{-1}\frac{1.097}{1.1688 + 0.100} - \tan 20 \text{ deg.}\right]$$

$= 1.1807$ teeth

$$\text{Tooth overlap} = \frac{T \tan\theta}{r} \times 57.3$$

$$= \frac{1.008 \times \tan 24 \text{ deg. } 37 \text{ min.}}{1.1688} \times 57.3$$

$= 22.6$ deg. overlap

$$\frac{22.6 \times 17}{360} = 1.068 \text{ tooth overlap}$$

Total number of teeth in contact
$= 1.1807 + 1.068 = 2.2487$ teeth

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